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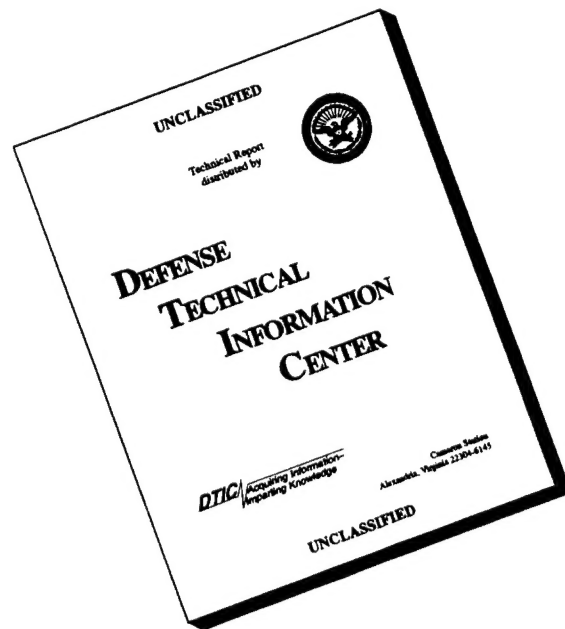
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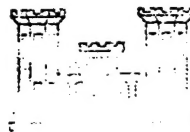


INTERIM CONTAINMENT SYSTEM
GROUNDWATER TREATMENT
ROCKY MOUNTAIN ARSENAL
DENVER, COLORADO

by

S. P. Miller

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September 1976

Final Report

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**Rocky Mountain Arsenal
Information Center
Commerce City, Colorado**

Prepared for Decontamination Systems Technical
Working Group, Edgewood Arsenal, Maryland

Conducted by U. S. Army Engineer Waterways Experiment Station
Soils and Pavements Laboratory
Vicksburg, Mississippi

PREFACE

This investigation was conducted during the period 17 May 1976 to 30 September 1976 by the Soils and Pavements Laboratory (S&PL) of the U. S. Army Engineer Waterways Experiment Station (WES). The study was authorized by IAO BT004, Aberdeen Proving Ground, Maryland, dated 13 July 1976 and IAO RM-56-7T, Rocky Mountain Arsenal (RMA), Denver, Colorado, dated 16 August 1976. .

This report was prepared by Mr. S. P. Miller of the Engineering Studies Branch, S&PL, WES, under the supervision of Mr. G. B. Mitchell, Chief, Engineering Studies Branch. Mr. C. L. McAnear was Chief, Soil Mechanics Division, and Mr. J. P. Sale was Chief, S&PL. Mr. W. O. Miller and Mr. W. L. Murphy of the Engineering Geology and Rock Mechanics Division, S&PL, developed parts of the project design criteria.

The assistance of personnel at RMA is gratefully acknowledged.

COL G. H. Hilt, CE, and COL J. L. Cannon, CE, were Directors of WES during the preparation of this report. Mr. F. R. Brown was Technical Director.

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Commerce City, Colorado

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INTERIM CONTAINMENT SYSTEM, GROUNDWATER TREATMENT
ROCKY MOUNTAIN ARSENAL, DENVER, COLORADO

Introduction

Background

1. The Decontamination Systems Technical Working Group, Aberdeen Proving Ground, Maryland, at the direction of the Program Manager, Installation Restoration, requested the U. S. Army Engineer Waterways Experiment Station (WES) to evaluate interim systems for containment/dewatering/recharging of contaminated groundwater at Rocky Mountain Arsenal (RMA). The WES was also tasked to plan acquisition and evaluation of geotechnical data for development of design criteria for the chosen system. This report does not address the treatment portion of the interim containment system.

Purpose and scope

2. This report will be used to develop the conceptual system into a project for construction and operation. After consideration of various system components in relation to several factors, e.g., geotechnical data, geochemical data, constraints, costs, the system described herein was selected. This report describes the chosen site, geotechnical data acquired, and system components selected, and provides design criteria for the system. The site chosen for the interim containment system is along part of the northern boundary of RMA near a small pond-like area primarily fed by groundwater and referred to as the "bog," Figures 1 and 2.

3. The objective of the interim containment system is to intercept the groundwater flowing ^{northerly} across the alignment of the system, treat it, and return it to the aquifer downstream of the dewatering component. This system will consist of four major components: dewatering wells, a groundwater barrier, a recharge component, and a treatment component, Figure 3. The dewatering wells will remove water from the aquifer and the recharge component will return it to the aquifer. To avoid

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movement of treated, recharged water back to the dewatering area, which would increase the volume of water to be treated, a barrier will be installed between the dewatering wells and the recharge component. Another use of the barrier will be to provide temporary underground storage of water to permit maintenance or repair of the treatment facilities without permitting contaminated groundwater to travel beyond the barrier.

Site Conditions

Geology

4. The geology of RMA consists of unconsolidated alluvial terrace deposits and eolian sand of ~~Recent to~~ Quaternary age overlying bedrock of clay shales and sandstone of the ~~Cretaceous~~ ^{Denver} ~~Denver~~ ^{Arapahoe} formation. Small bedrock outcrops occur on a few of the hills within the Arsenal. Near the northern boundary, bedrock is predominantly clay shale overlain by 20 to 30 ft of terrace sands and gravels and eolian clays and sands. ~~The interim system will be concerned only with the bedrock and materials above.~~ Topography is gentle with elevations in the system area varying from approximately 5130 MSL to 5160 MSL. Remnants of ancient terraces form low hills in the area.

Groundwater

5. The shallow aquifer consists of alluvial materials overlying the bedrock. The aquifer and water table elevations have been charted in several publications.^{1,2,3} Water levels taken from borings during the subsurface site investigation are recorded on the soil profiles, Plates 1-7. The water level is steady with minor seasonal variations. Saturated thickness in the site area varies from 10 to 25 ft, Plates 1-7, and the gradient is approximately 0.01 to 0.005 toward the north.^{1,2} The bottom of the bog apparently intercepts the groundwater table and is supplied directly from the aquifer. This interpretation is substantiated by observation, borings, and bulk sampling in the bog area.

Subsurface investigation

6. The subsurface investigation consisted of 24 borings drilled in July 1976 and presented in Plates 1-7 which give boring locations and soil profiles. Samples were taken at 5-ft increments and/or change in stratum. Three different types of borings were made: undisturbed (UD), drive (D), and auger (A). Samples from the 8 UD borings were taken with a 3-in.-diam open Shelby tube in cohesive soils and with a 2-in. split spoon for cohesionless soils. The 2-in. split spoon was used for all soils encountered in the 8 D borings. Jar samples were taken and blow counts recorded for all drive samples. The 8 A borings were visually classified. All borings penetrated the weathered zone of the bedrock and all samples were transported to the WES for classification and testing.

Soil properties

7. The overburden soils are generally lean clays (CL) overlying sands (SC, SP) which, in turn, overlay the weathered shale (usually a fat clay CH or inorganic silt MH) or weathered sandstone (usually lean clay and silty sand CL-SM or silty sand SM) above the unweathered bedrock. This general trend is apparent from the soil profiles, Plates 1-7, which are classified from the boring logs.

8. Soil samples from the subsurface investigation were tested at the WES Soils and Pavements Laboratory (S&PL) to determine index properties and strengths. Grain size distribution curves, laboratory classifications, liquid limits (LL), plastic limits (PL), plastic indexes (PI), and water contents for samples from UD and D borings are shown on Plates 17-80. Unconsolidated, undrained triaxial tests were performed on selected UD samples, Plates 9-16. A Unified Soil Classification and legend are provided in Plate 8.

Pumping tests

9. Three pumping tests were made in the alignment areas, Figure 2, during August 1976 by the WES S&PL to determine local permeability and yield characteristics of the aquifer. Analysis of these tests gave a permeability of approximately 210 ft per day, which was used with gradient and aquifer cross sectional area to calculate groundwater flow across the system alignment.

Major System Components and Associated Design Criteria

Dewatering wells

10. A dewatering system to remove the contaminated water from the aquifer for treatment is shown in Figure 4. The dewatering alignment should be located 200 ft from the barrier and be 1400 ft in length. It is positioned between Station 26+00 and 40+00 of the original stationing of the north and south alignments as shown in Plates 1-7. Normal northerly groundwater flow across this alignment is expected to be 135 gallons per minute (gpm). Since this flow is expected to fluctuate, the maximum capacity of the dewatering system should be 125 percent of expected flow, or 169 gpm. This is the approximate expected capacity of the treatment component. The dewatering system should also have the capability to evenly remove the minimum flow of 75 percent of normal, or 100 gpm. Therefore the separate wells must be capable of handling a variation in flow due to these fluctuations and also due to local differences in flow along the alignment. The wells must fully penetrate the aquifer with well screen length equal to aquifer thickness. A general well spacing of 200 ft was chosen. This spacing has been varied to accommodate nonuniform flow across the dewatering alignment and should result in approximately 5 ft of drawdown in the wells. Pumps should have automatic controls to maintain a set drawdown once the required drawdown to operate the system is established. The distance between the barrier and dewatering alignment is set to make optimum use of underground storage as described in paragraph 11 and Figure 5. Figure 4 presents the dewatering and barrier alignments in plan and the dewatering alignment in profile, west to east. Figure 5 is a schematic cross section of the entire system, south to north. The grain size curves provided as Plates 17-80 can be used for sizing of well screen openings.⁴

Groundwater barrier

11. A groundwater barrier consisting of a bentonite slurry cut-off trench extending into the bedrock should be located from Station 26+00 to 40+00 of the northern system alignment, Plate 2, as shown in Figure 4.

This barrier will block movement of treated water from the recharge area back to the dewatering wells, thus preventing recycling of water in the treatment process. The barrier will also provide underground storage as shown schematically in Figure 6. This potential storage could be used during periods of dewatering system shutdown for maintenance problems or treatment delay. The total amount of storage is approximately 400,000 gallons which would be 2 days flow at the normal expected flow of 135 gpm. This amount assumes well drawdown as shown in Figure 4 and a porosity of 0.40 in the storage strata.

12. The slurry should be a mixture of bentonite, water, and any desired additives, and will serve to stabilize the trench during excavation.^{6,7,8} The trench should extend 2 ft into weathered bedrock (CH) in clay shale areas and to the bedrock in sandstone areas, be a minimum of 24 in. in width, and have a structural cover. A structural cover is required to carry any load applied on or in the immediate vicinity of the slurry trench (e.g. traffic or working platforms) since it cannot support a load. The trench should be 1400 ft in length and an average of 27 ft in depth. These are approximate dimensions based on limited soil sampling, therefore determination of actual construction dimensions should be made by a knowledgeable soils engineer based on field conditions encountered during construction. Specifications should be developed defining water quality factors such as pH, hardness, and deleterious substances. Industrial suppliers of bentonite have guides for desired slurry water quality. If neither local well water nor the bog water meets these standards, alternative sources of water should be considered. A model study was conducted to discover if the groundwater in the system area would have any detrimental initial gross effects on the bentonite.⁵ The study lasted 10 days using groundwater from the interim containment system area. No detrimental effects were noted.

Recharging component

13. The treated water must be restored to the aquifer through a recharge method downstream (north) of the barrier. The bog area presents a natural and readily accessible entrance to the aquifer. The rate of movement of the recharged water in the aquifer will vary

with the head maintained in the bog. In order to use the bog for recharge, all fine-grained material in the bottom of the bog above the aquifer should be removed. From consideration of aquifer area, aquifer permeability, and required gradient, the bog area should be able to recharge the aquifer at the maximum dewatering/treatment rate of 169 gpm, with approximately 1 ft of head above natural groundwater level. Lower areas of the bog boundary may require a dike to accommodate this water level. It is assumed that the treated water will be of relatively high quality and should pose only a minor, if any, clogging problem in the recharge area.

14. If the bog is retained in its present configuration for recharge, excavation is expected to be approximately 12,000 cu yd based on the soil borings. Actual quantity should be determined by a knowledgeable inspection of the bog to insure removal of all fine-grained material above the aquifer. This excavated material could be used to form part of the small dike referred to in paragraph 13. Side slopes of the excavation and/or dike should not exceed 1 vertical on 2 horizontal.

General considerations

15. Further considerations in the design of the interim containment system must include provision for above-ground storage of water to handle short-term differences in pumping and treatment rates and other contingencies, and a system to transport water from the dewatering system to the treatment location and, after treatment, back to the recharge area. These designs should consider such factors as safety, effect of contaminants on all components, treatment location, and cold weather precautions.

16. Monitoring of the groundwater system prior to and during construction and operation is necessary to assess the effectiveness of the system and provide input to operational variables, e.g. pump rates, recharge rates. Obviously, water quality and location must be closely observed. This need can be accomplished by installing observation wells and incorporating existing observation wells into a monitoring program for the interim containment system. It is important that this

program be initiated as soon as possible to establish general groundwater quality and level prior to construction and operation of the interim containment system. This, with existing data, will establish conditions prior to intervention by the system.

17. Observation wells capable of providing water level measurements and water quality sampling should be installed. Elevations of the tops of riser pipes should be established and protection from damage and contamination provided for during construction and operation. Any necessary access requirements for the installation or reading of new or existing observation wells located off the Arsenal should be considered. Records of water level and quality should include the bog (recharge component) and the dewatering wells. Readings of water level should be made biweekly prior to and during construction, daily during initial system operation, and over longer time periods as a stable condition develops. Water samples should be taken as necessary to determine the effect of the interim containment system on water quality.

18. Figure 7 depicts a plan for placing observation wells for use in a monitoring program. The observation wells are listed in Table 1 by number and purpose. Readings from these wells, the bog, and the dewatering wells may be used to produce groundwater elevation and quality contour maps and groundwater elevation cross sections to interpret the effect of the interim containment system on the groundwater and determine operational variables such as pumping rates and recharge rate. This plan may require adjustment or additional observation points as monitoring requirements develop.

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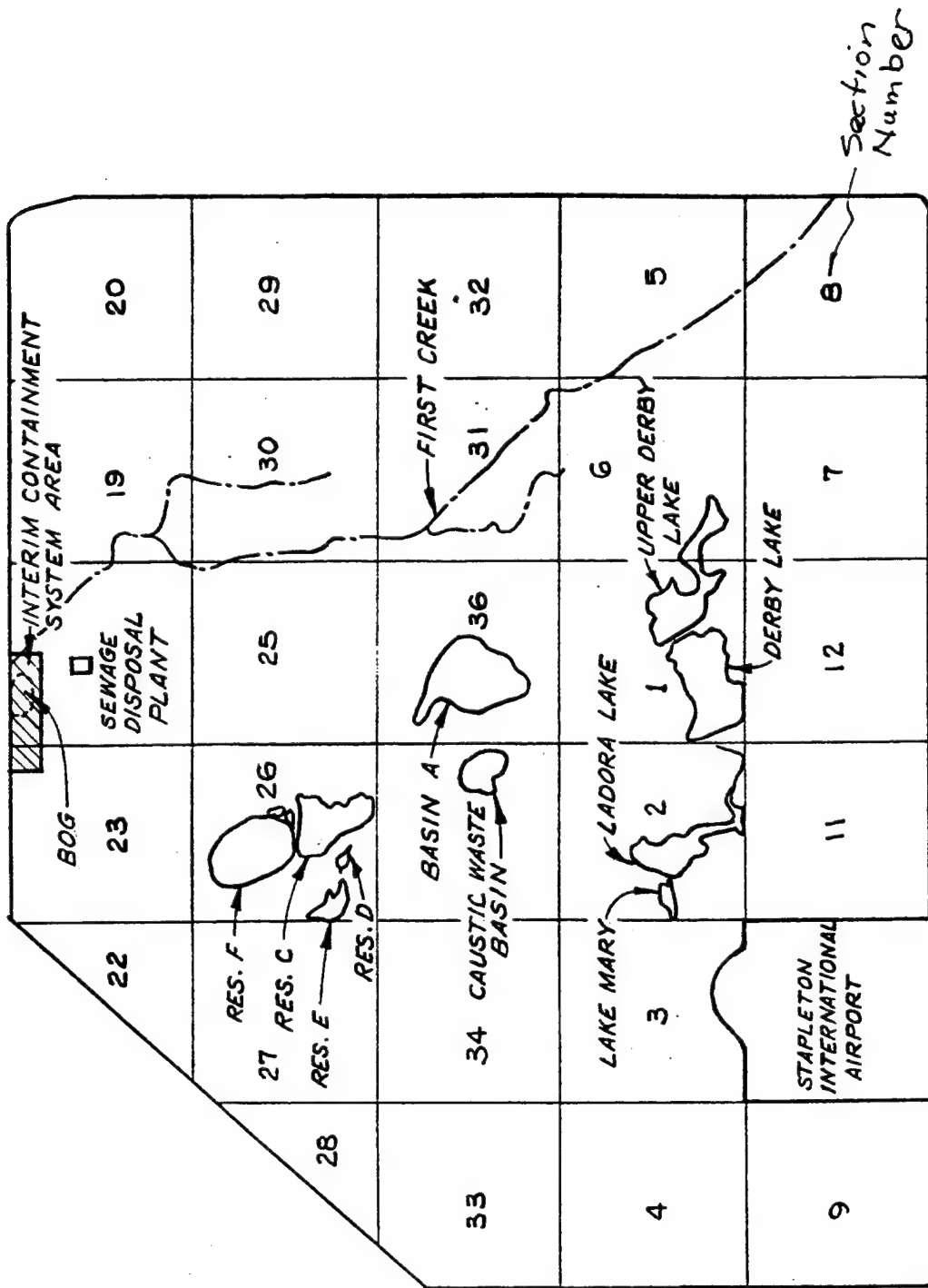


Figure 1. Interim Containment System location - Rocky Mountain Arsenal, Denver, Colorado

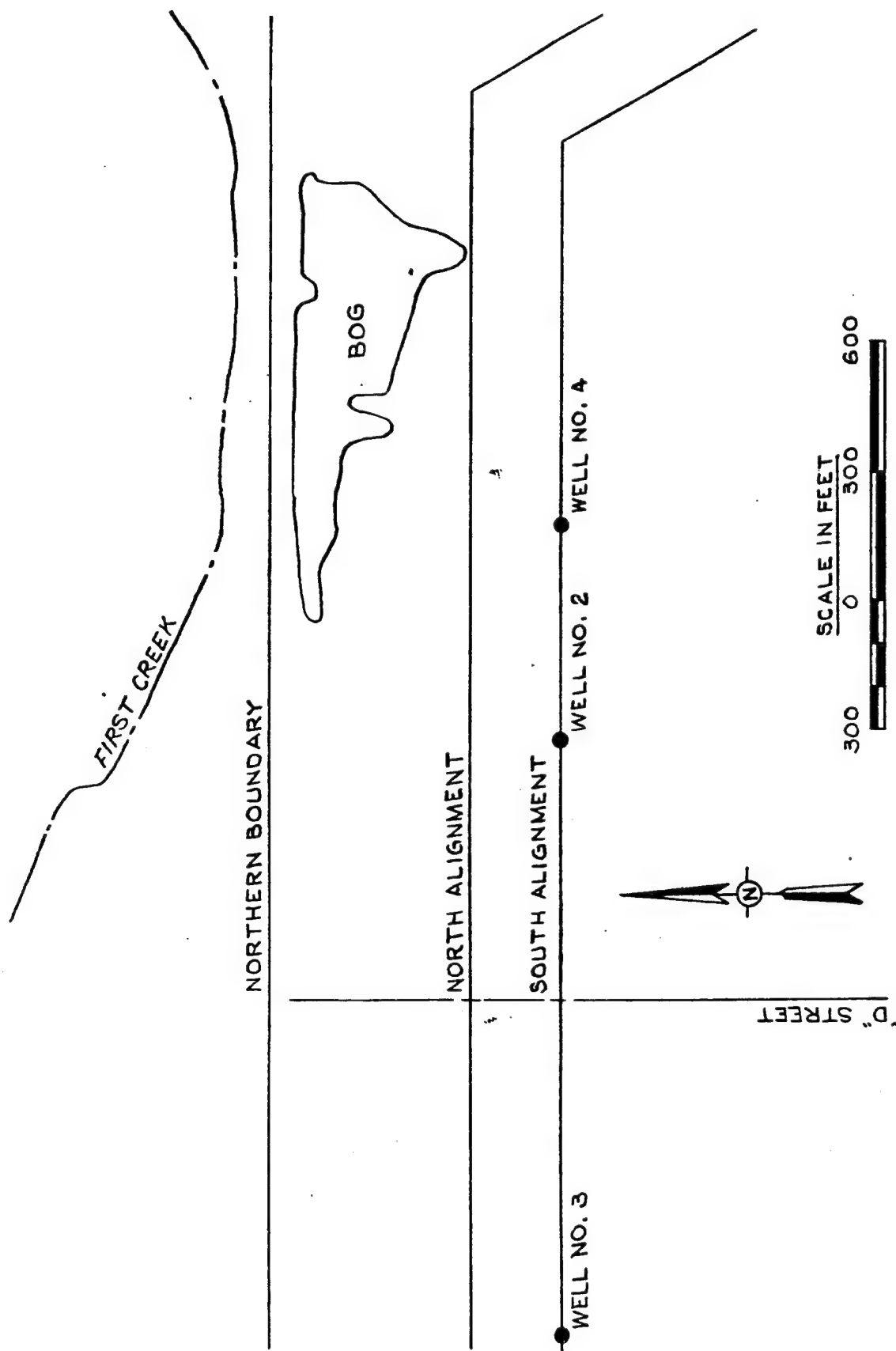


Figure 2. Subsurface investigation alignments and pumping test locations

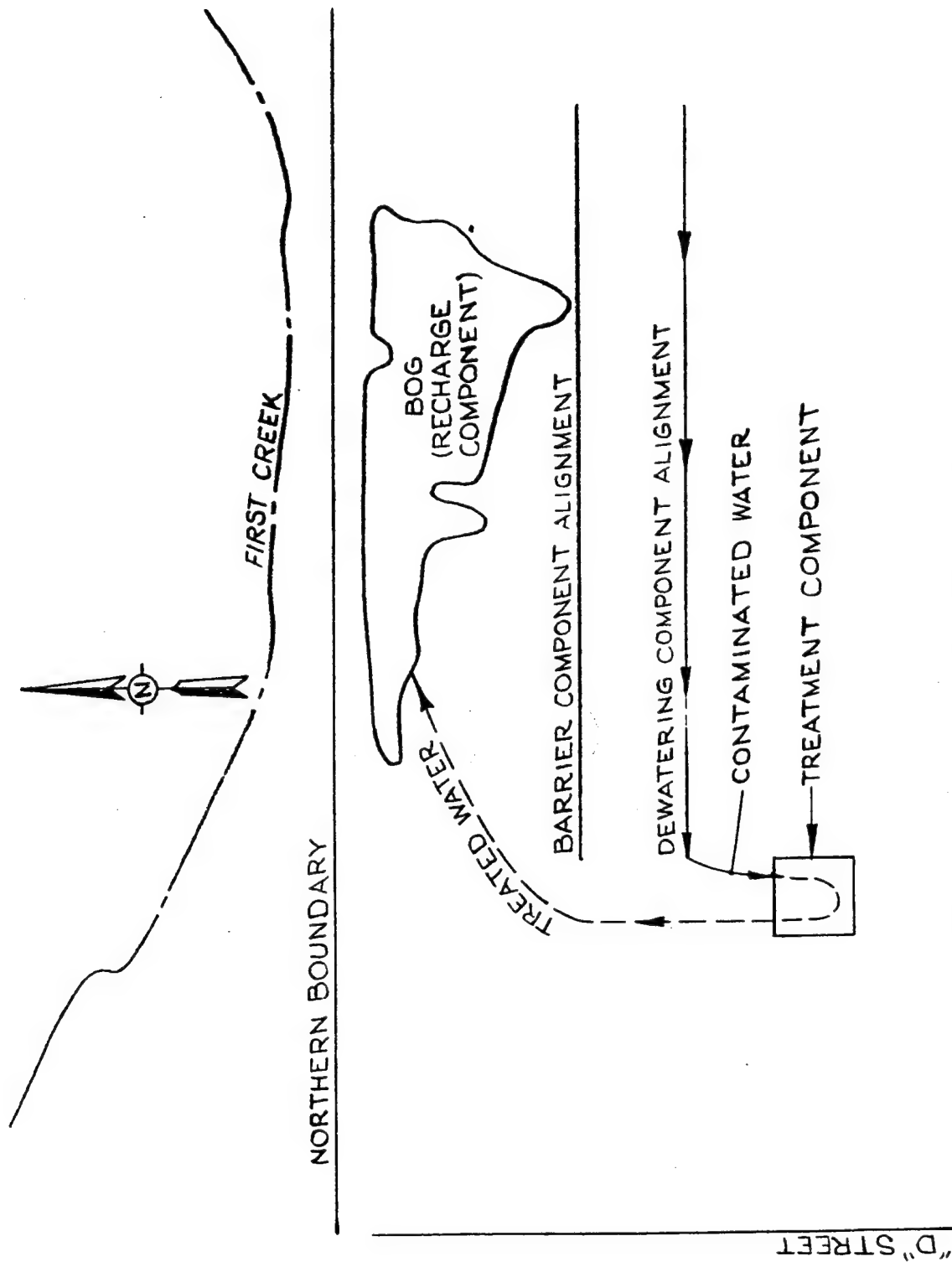
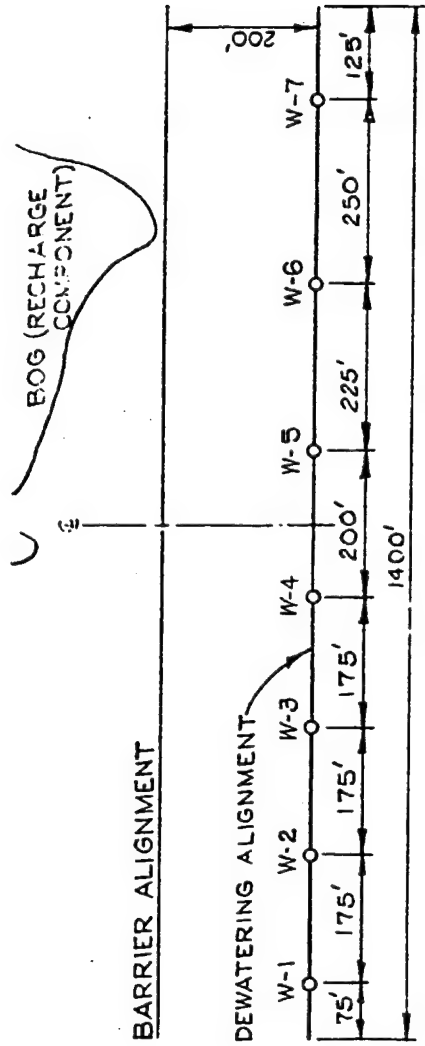


Figure 3. Interim Containment System components



NOTE: Q = DISCHARGE
W-1 = WELL NUMBER

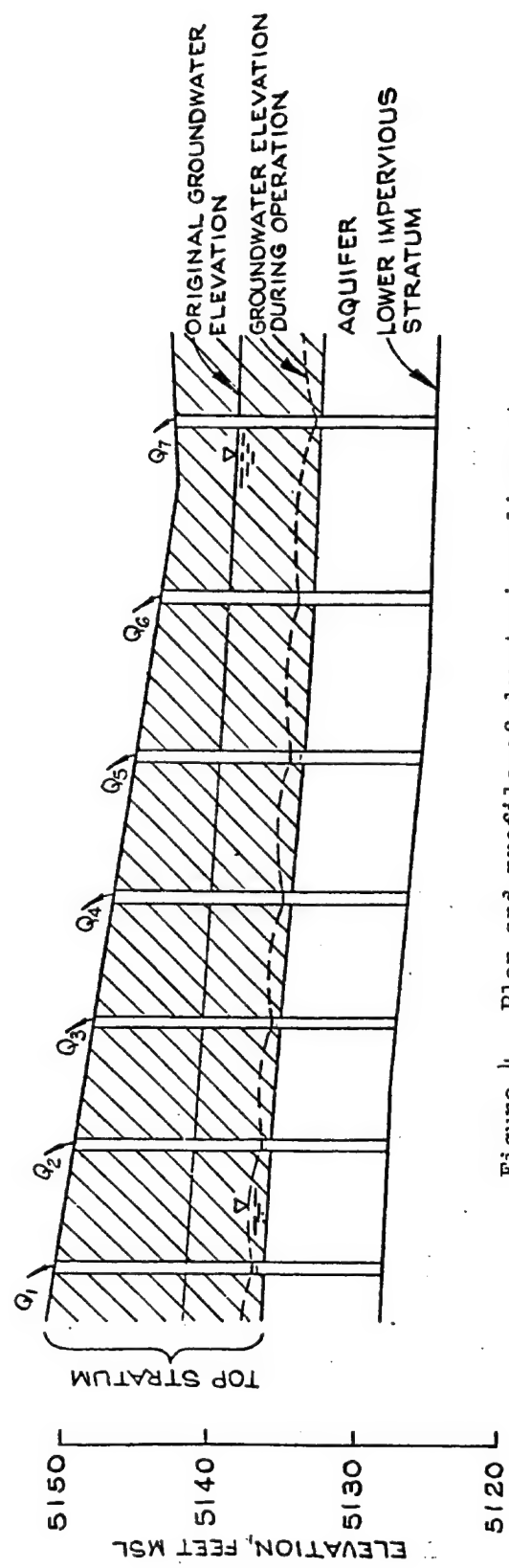


Figure 4. Plan and profile of dewatering alignment

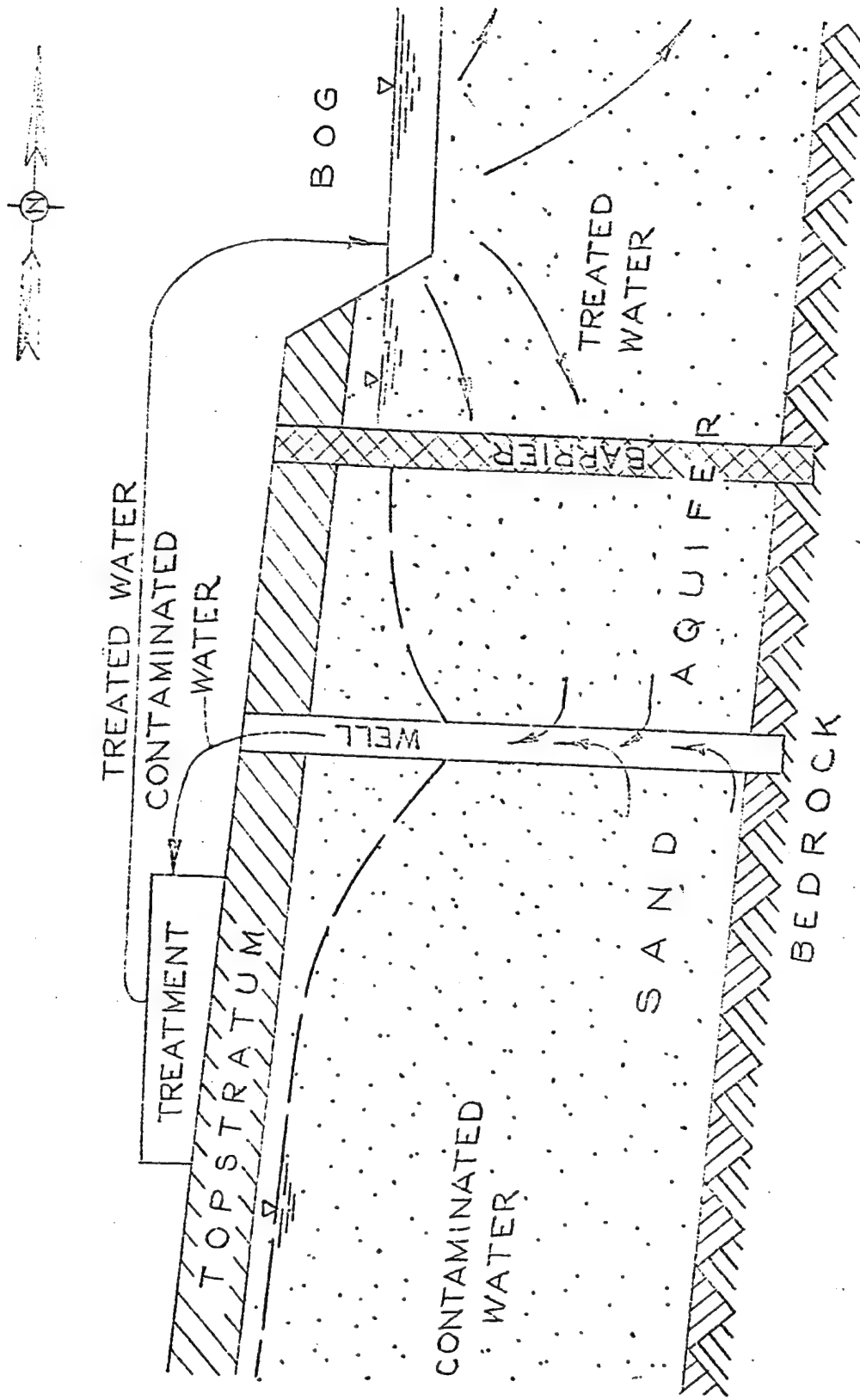


Figure 5. Schematic diagram of Interim Containment System, RMA

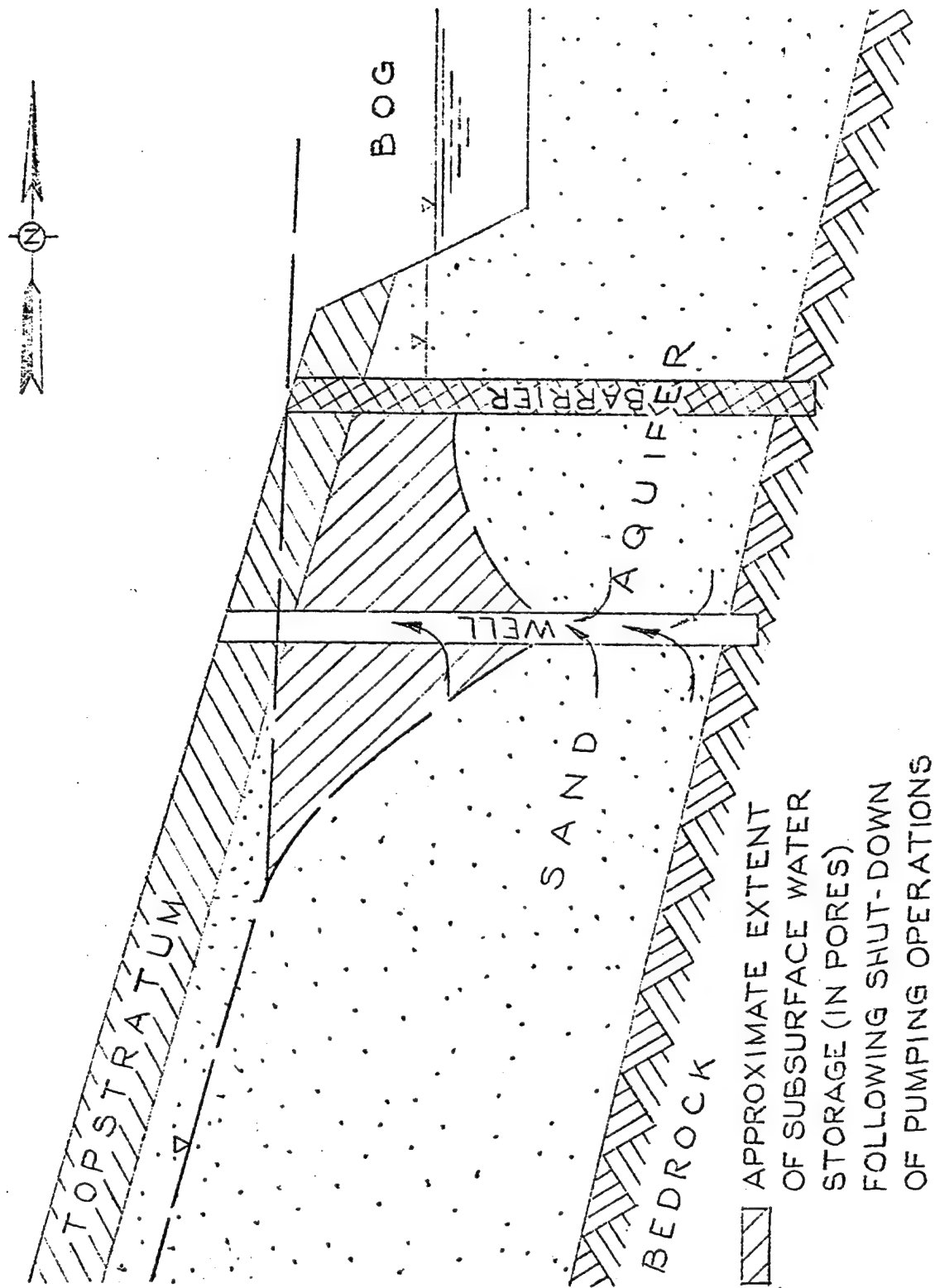


Figure 6. Schematic diagram of Interim Containment System subsurface water storage, RMA

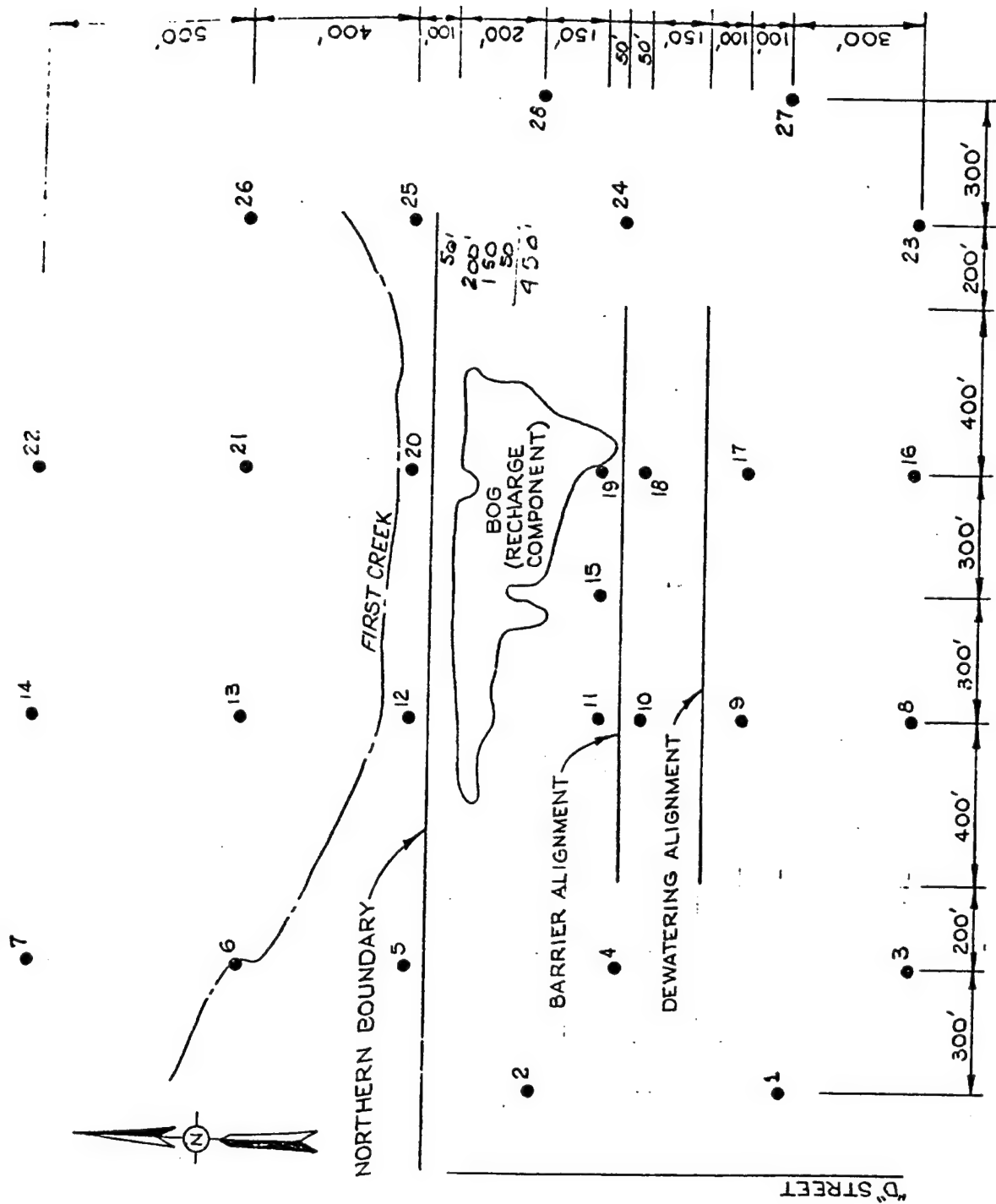
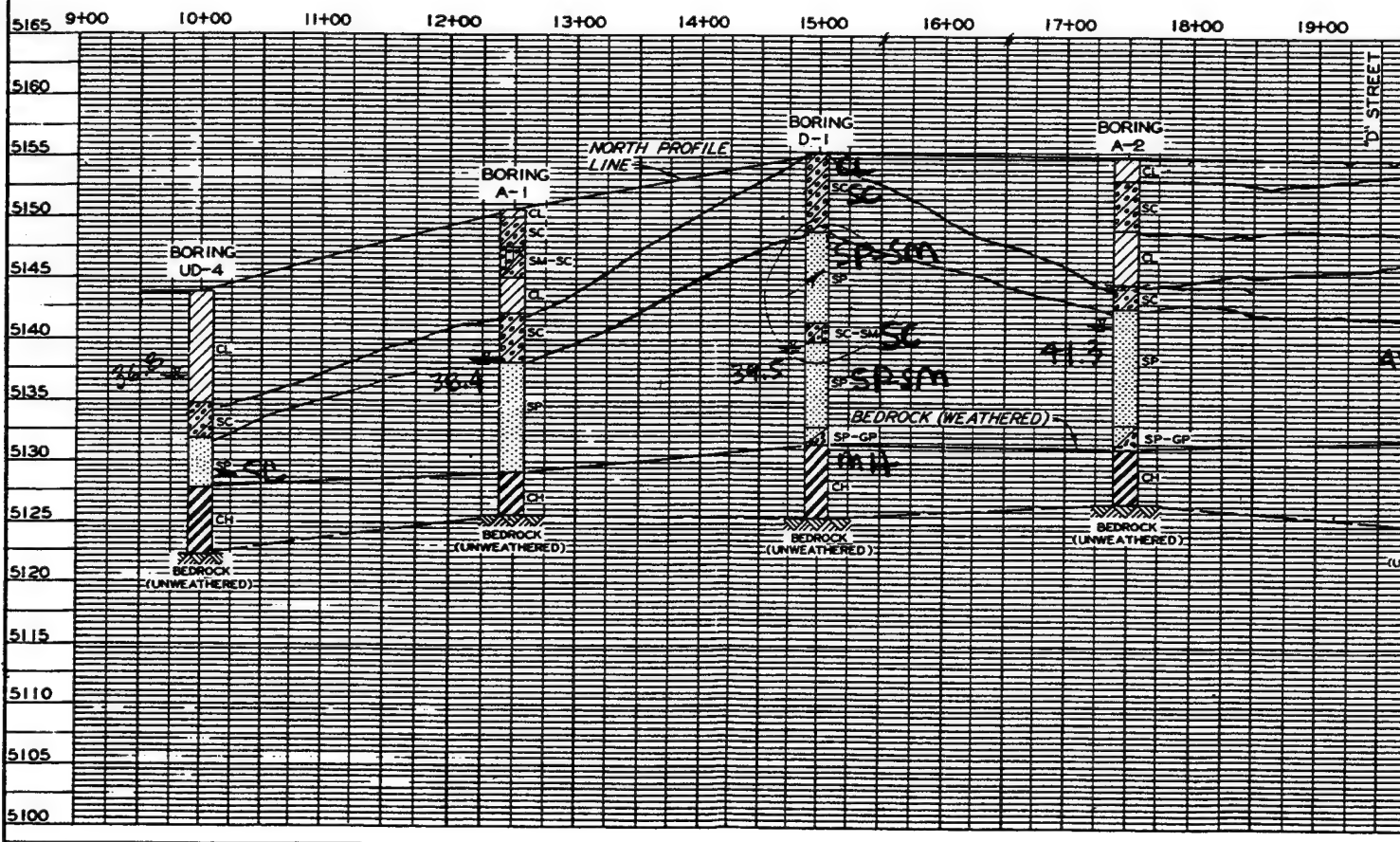
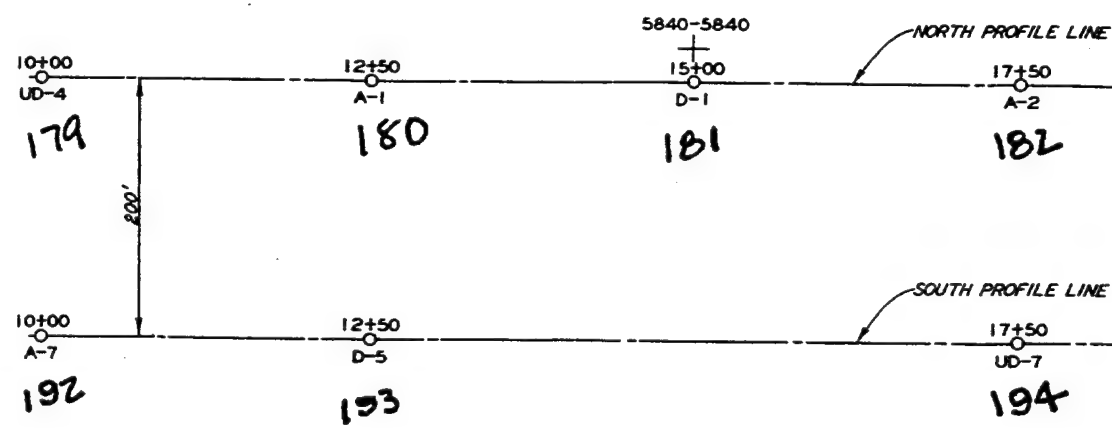


Figure 7. Groundwater monitoring plan

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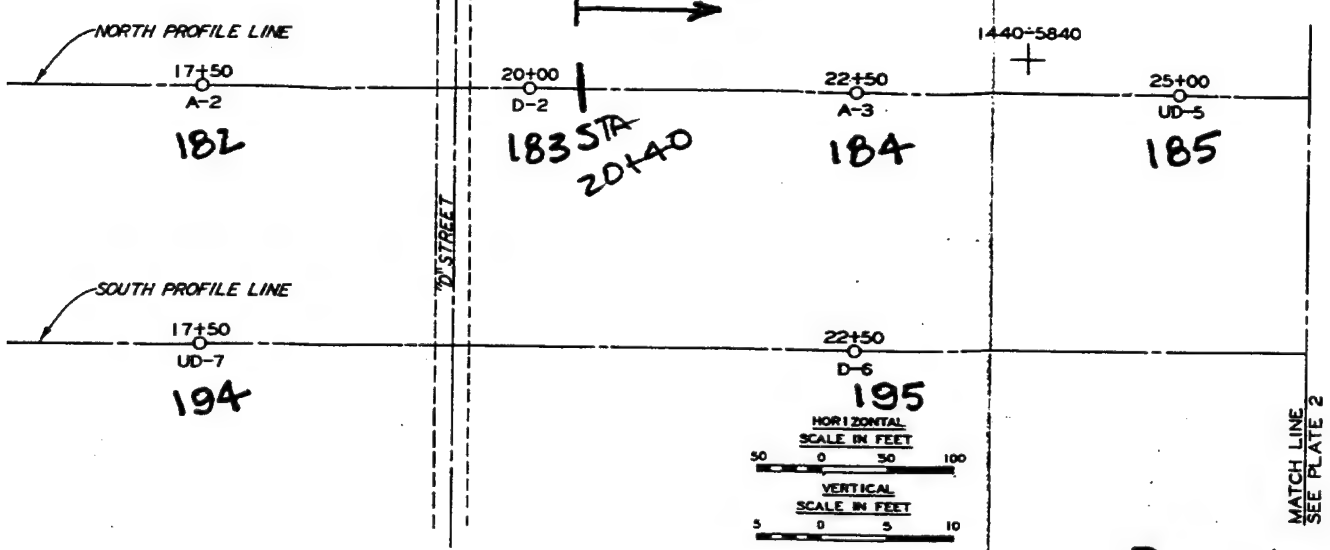
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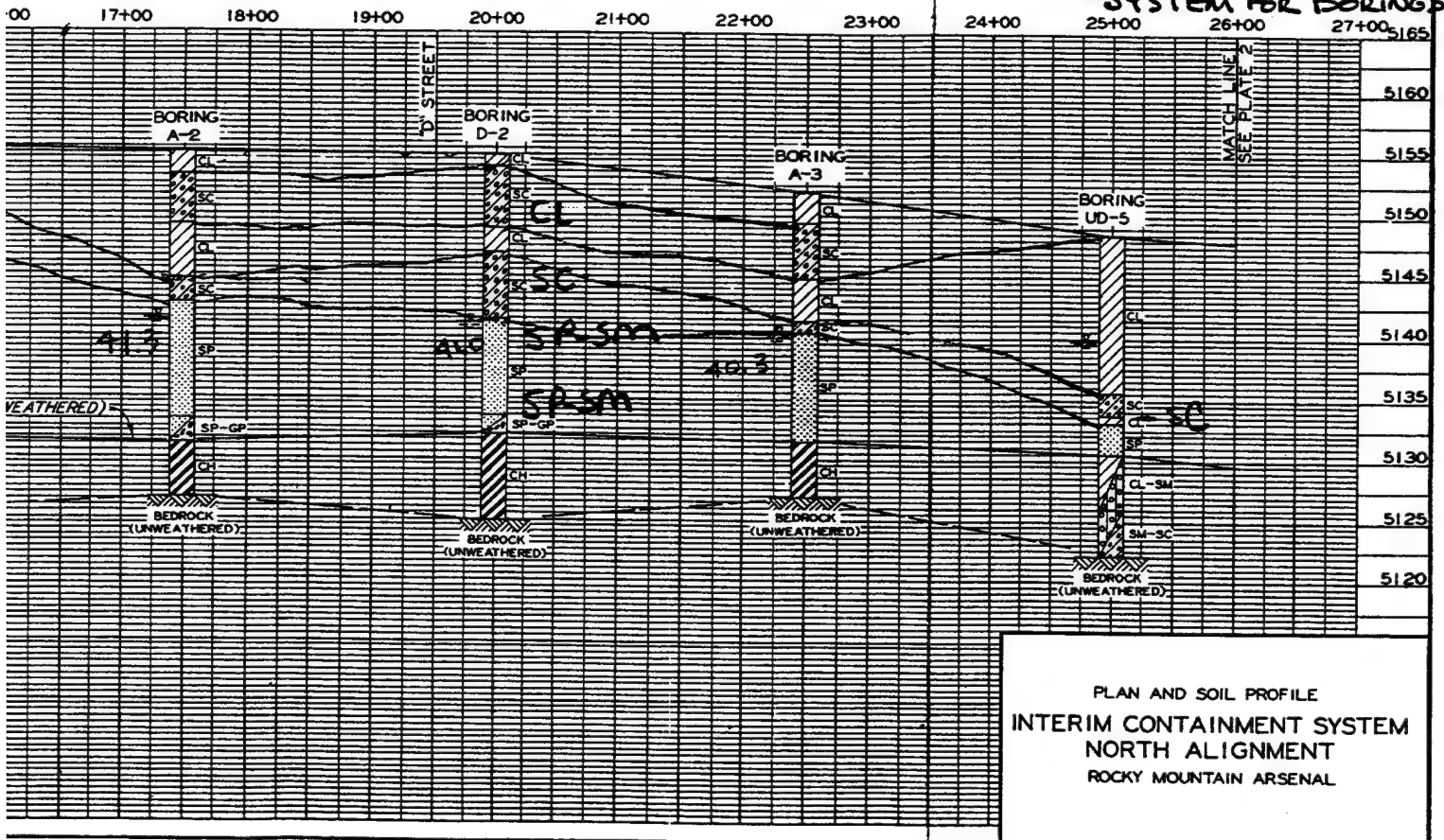
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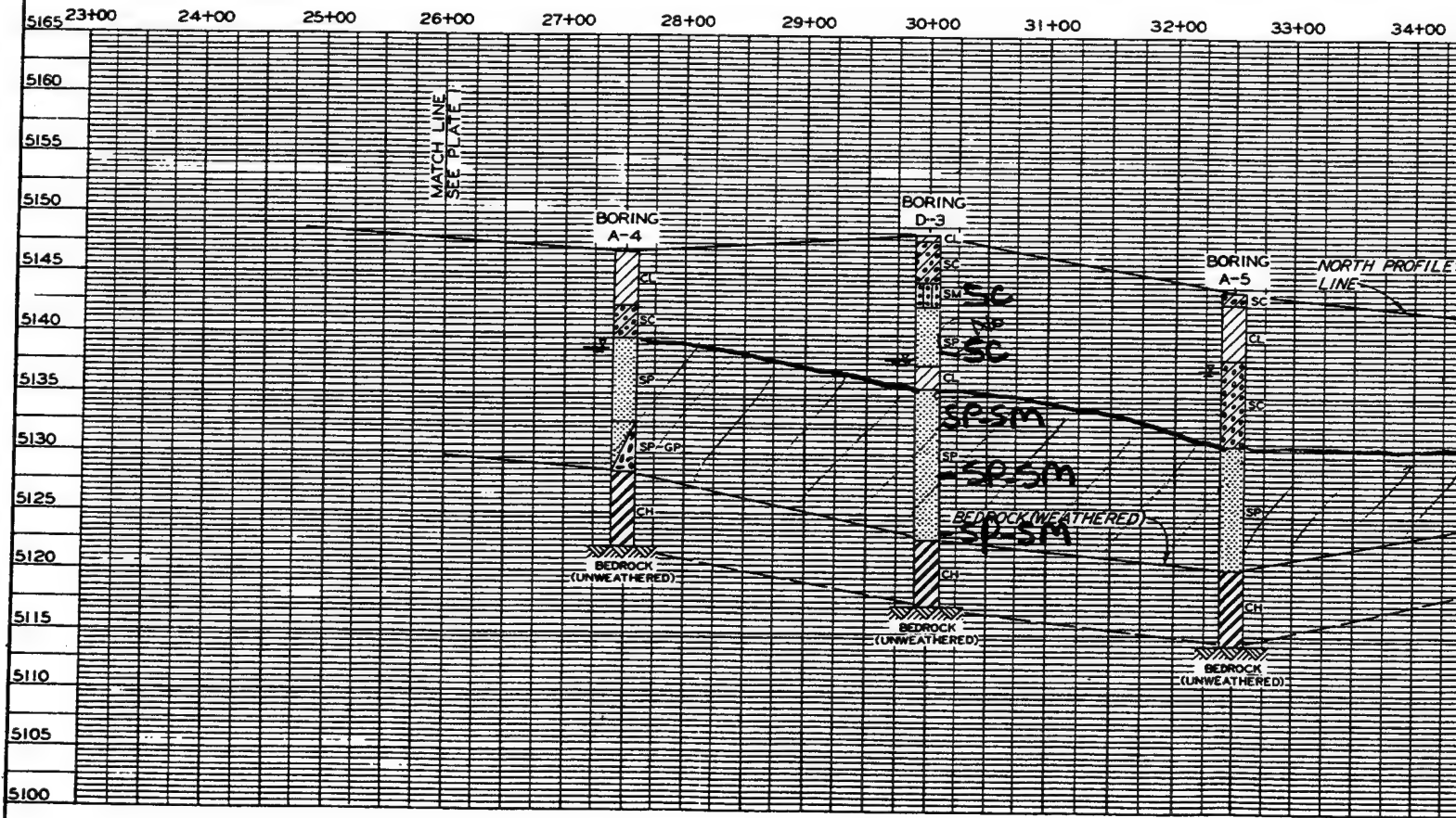
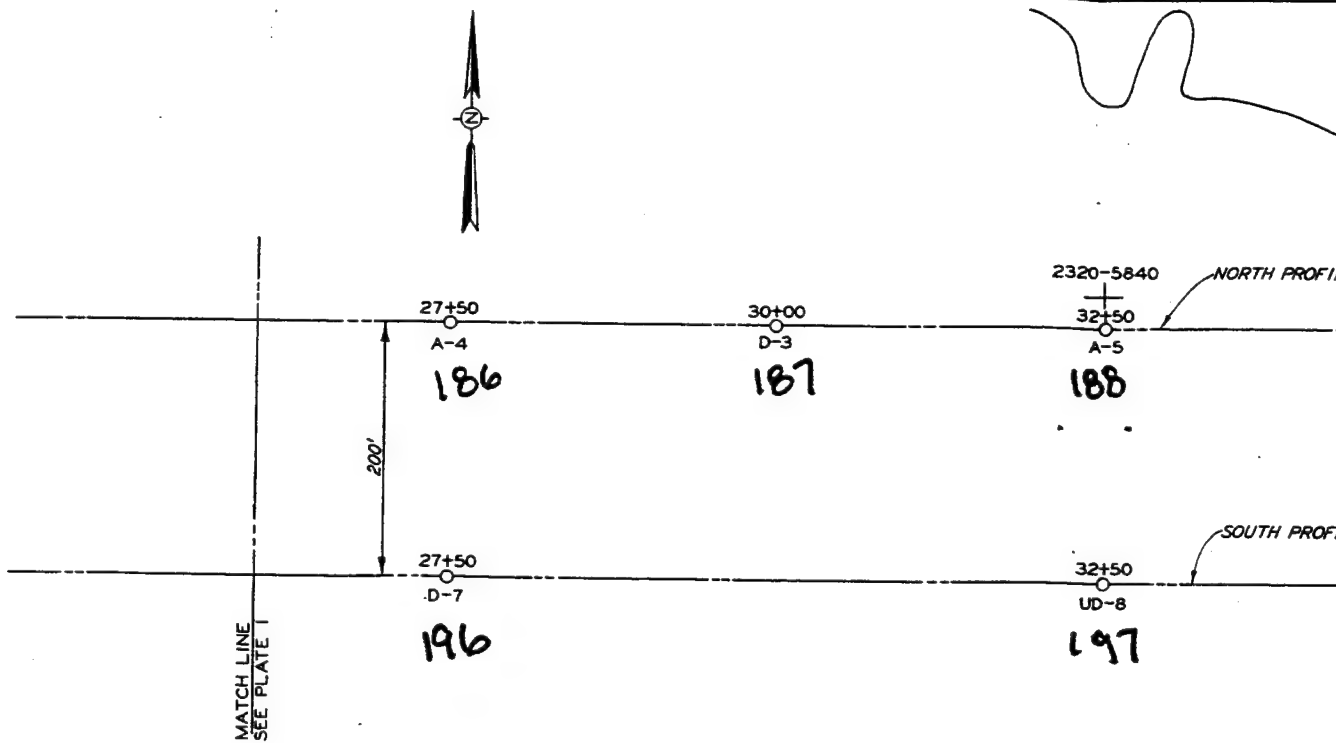
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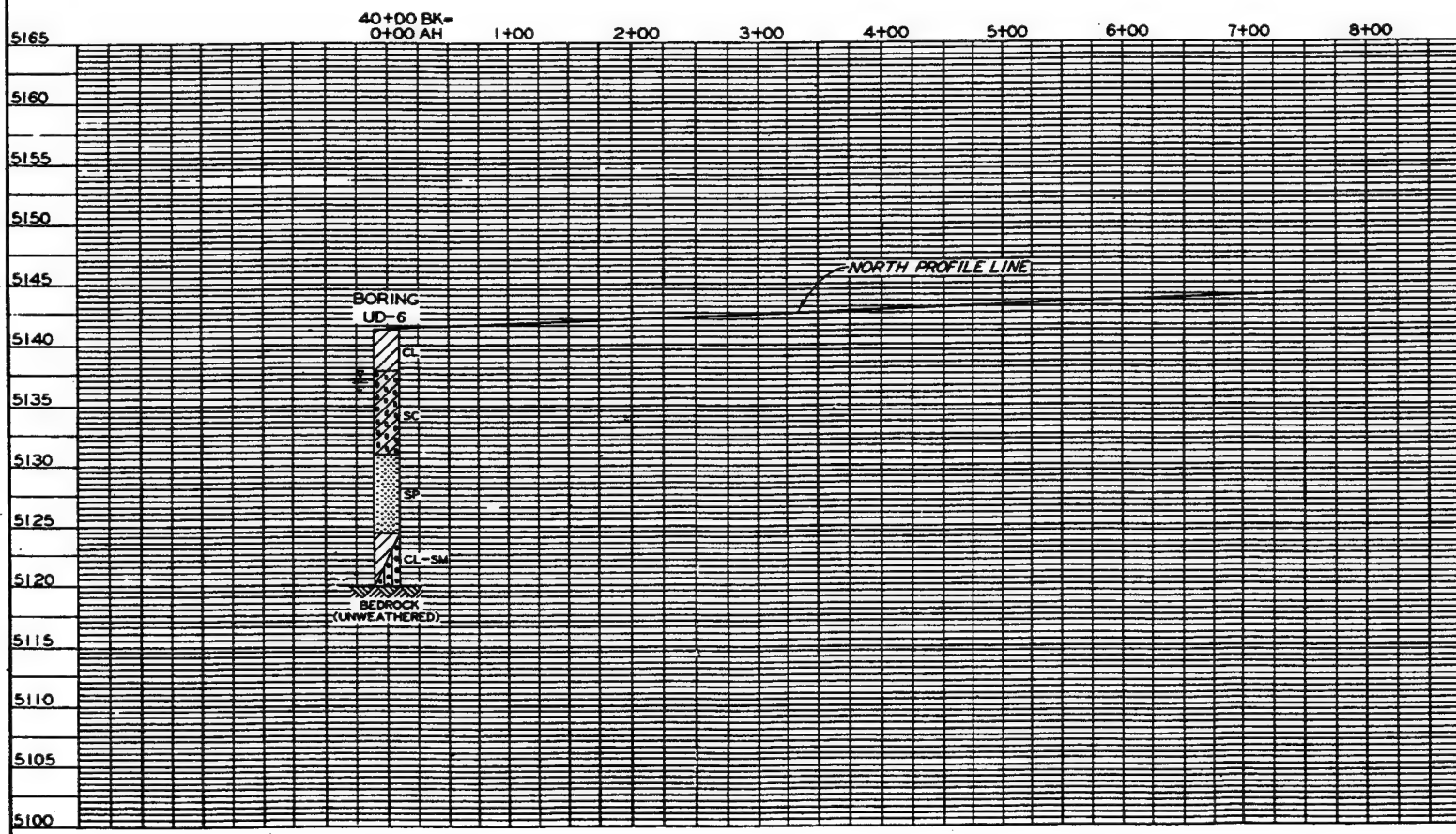
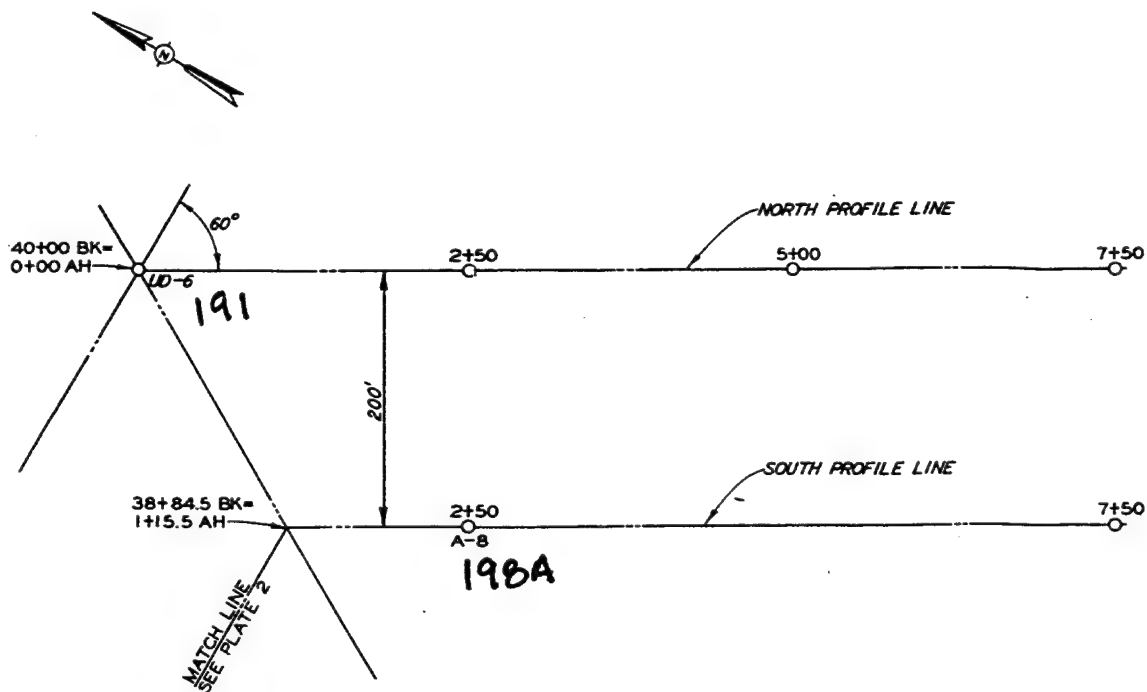


BWG NOS. ARE
RMA NUMBERING
SYSTEM FOR BORINGS



PLAN AND SOIL PROFILE
INTERIM CONTAINMENT SYSTEM
NORTH ALIGNMENT
ROCKY MOUNTAIN ARSENAL





NORTH PROFILE LINE

5+00

7+50

SOUTH PROFILE LINE

7+50



5+00

6+00

7+00

8+00

5165

5160

5155

5150

5145

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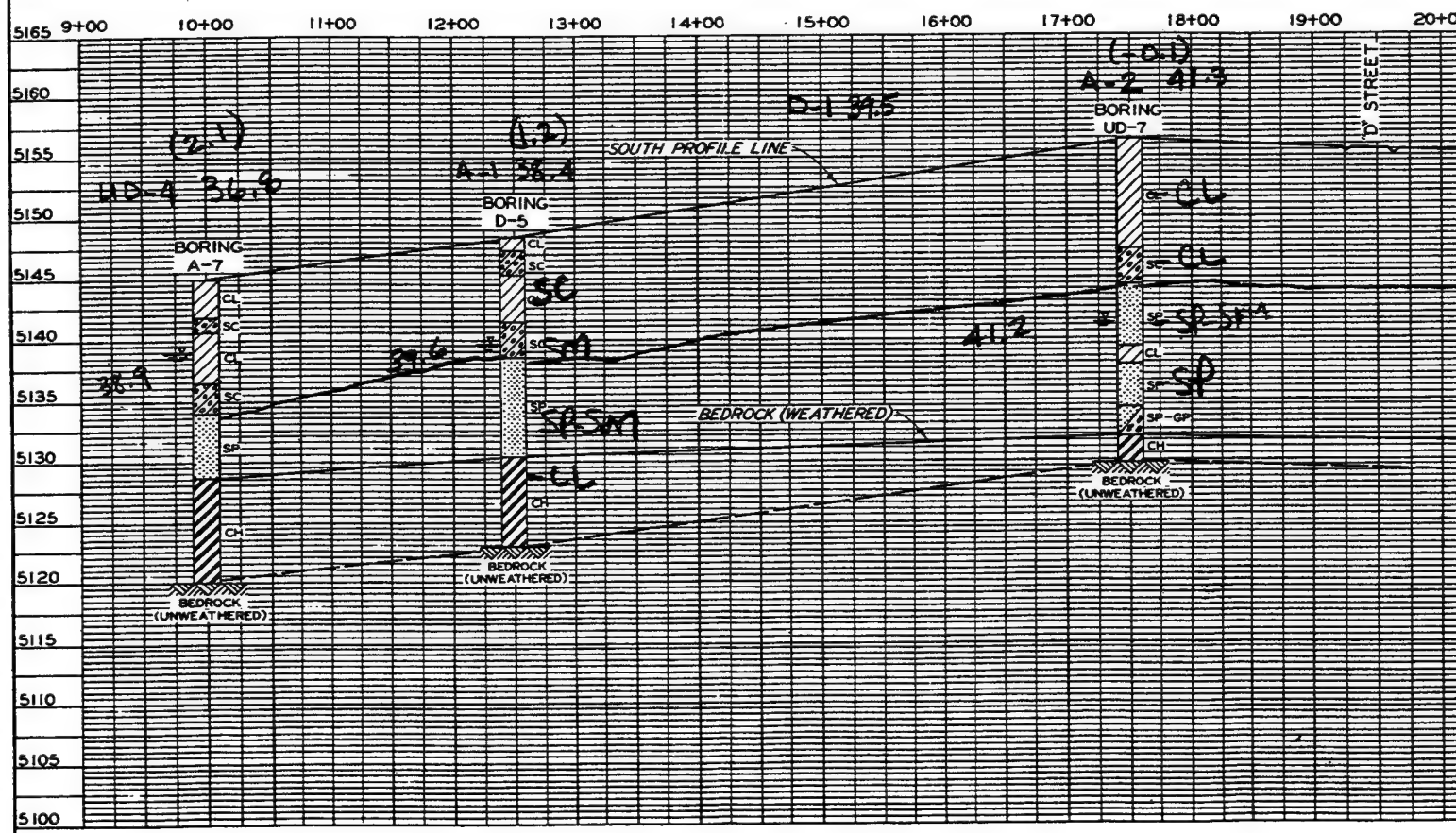
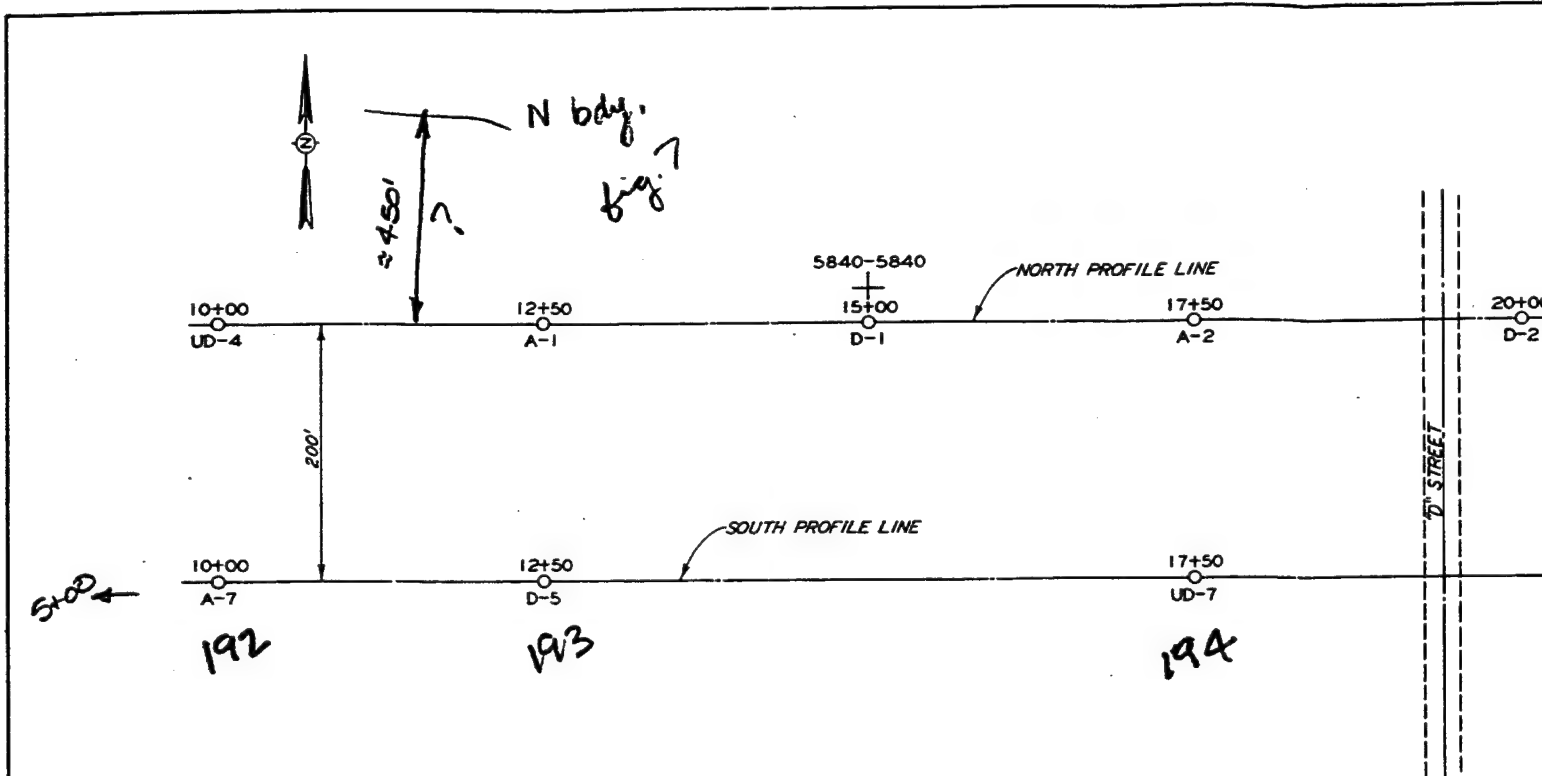
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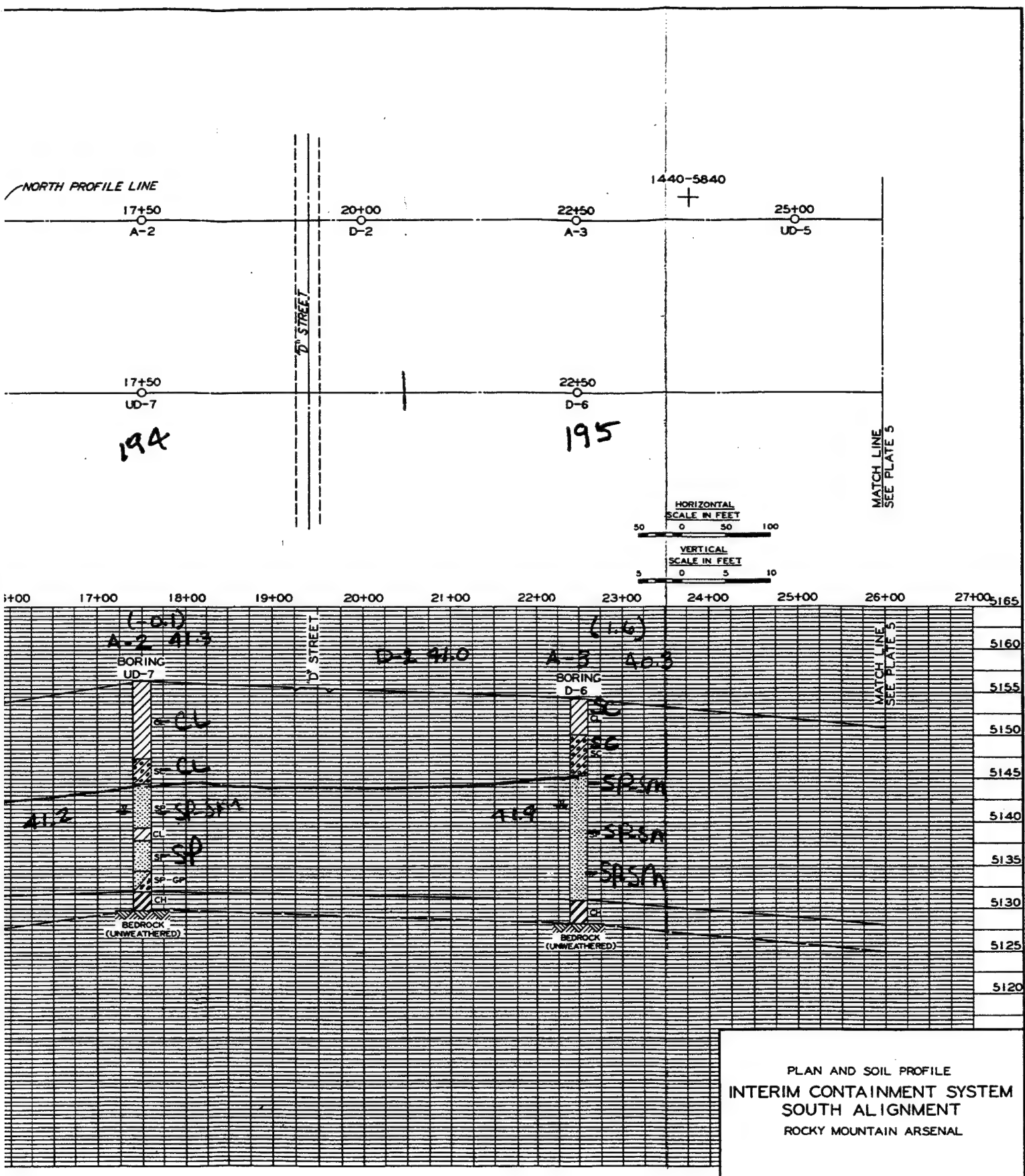
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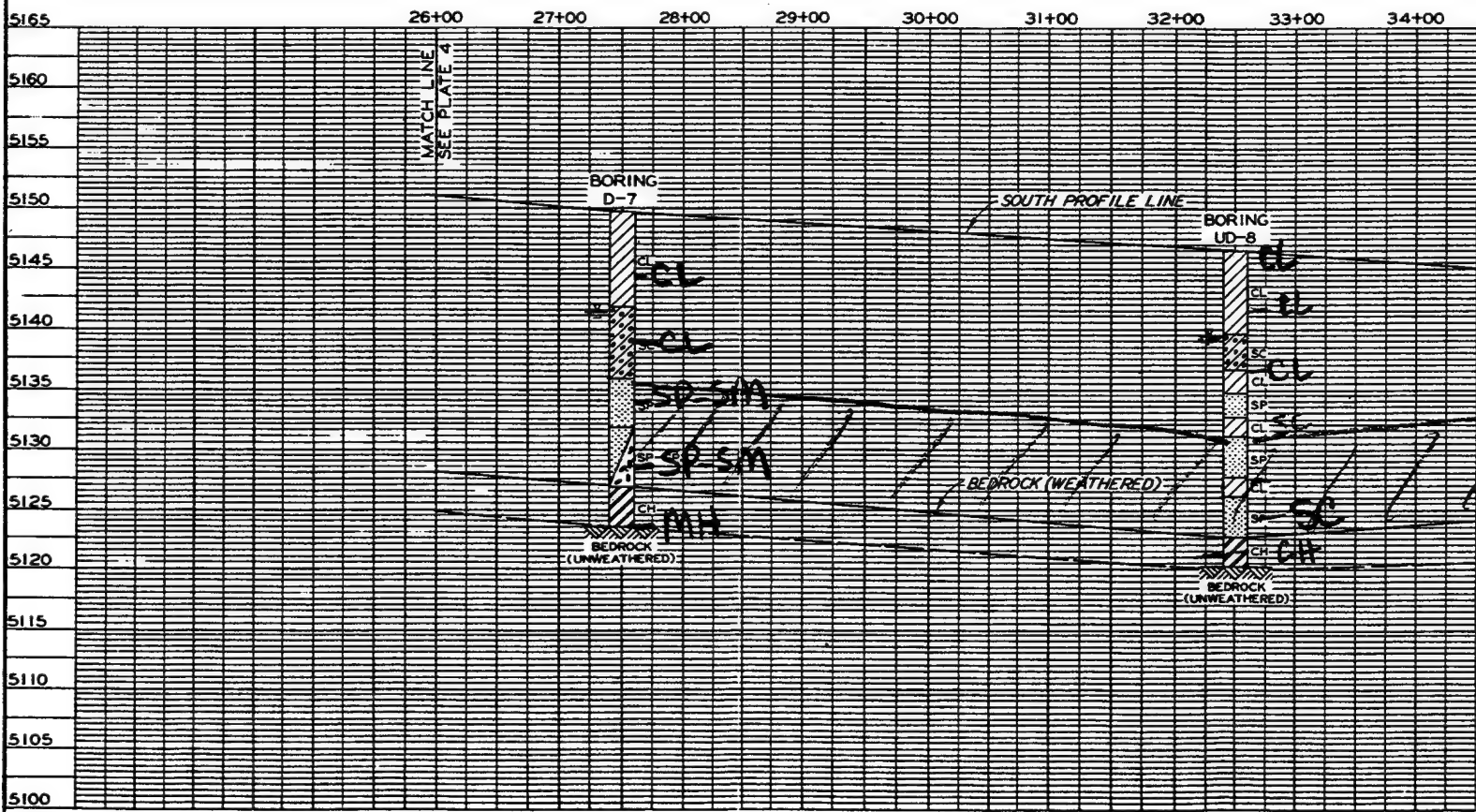
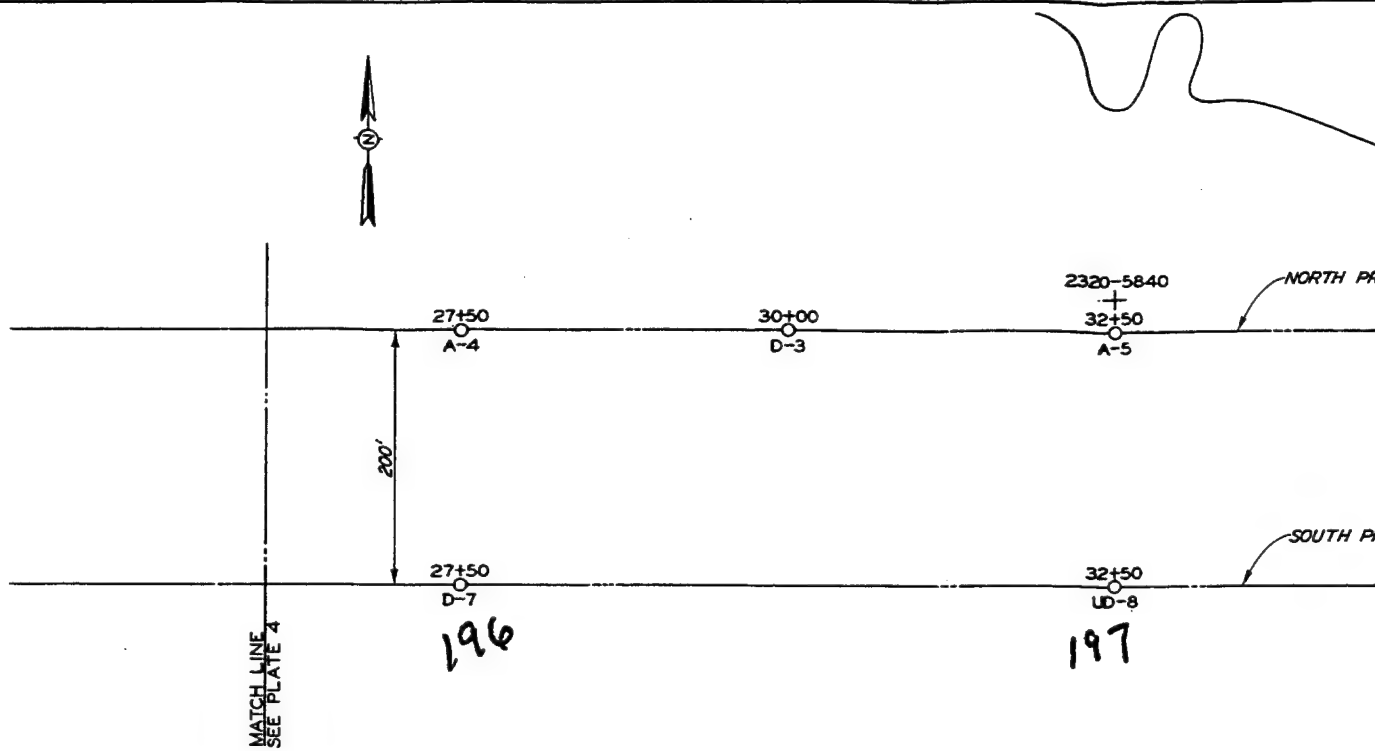
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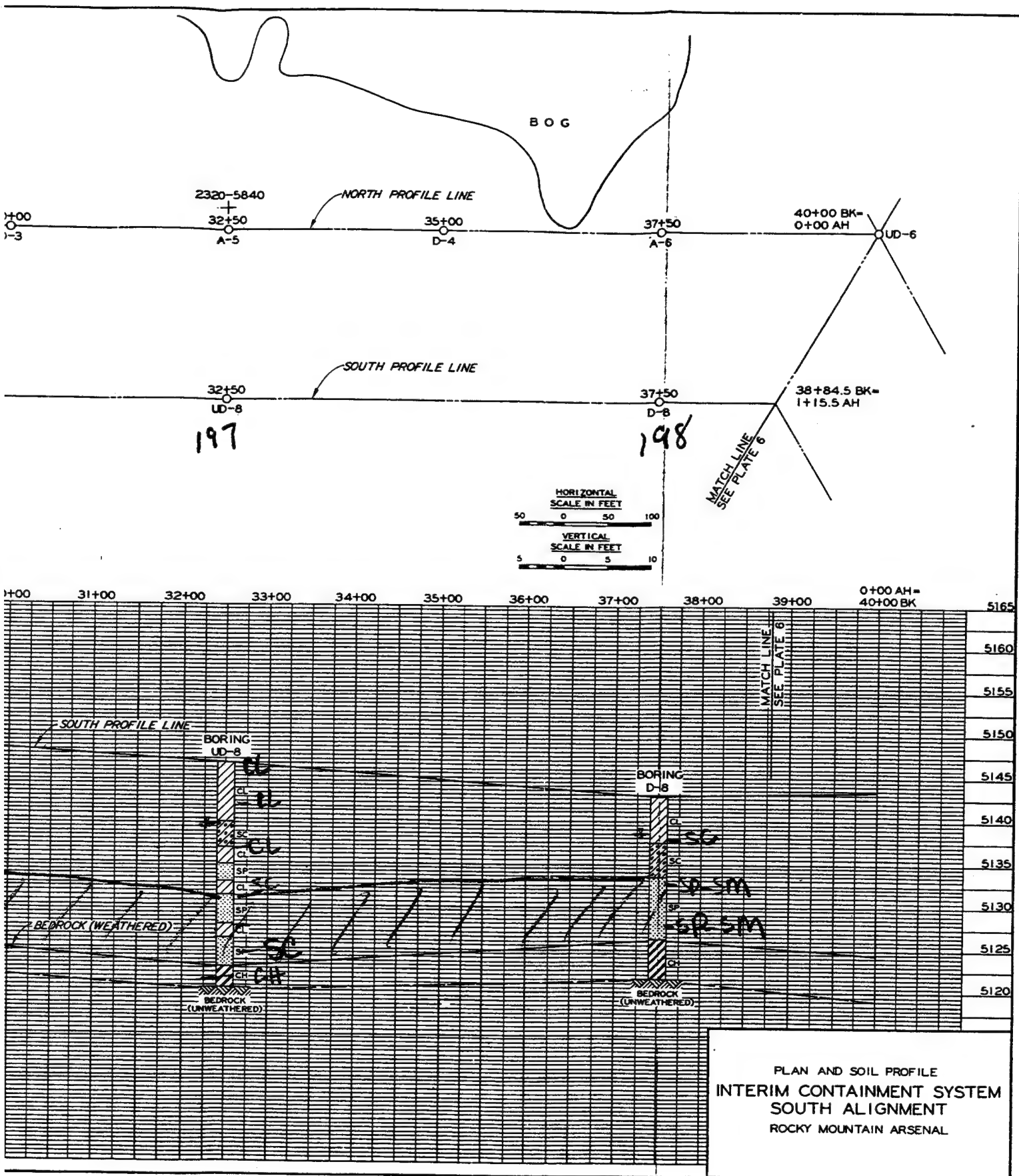
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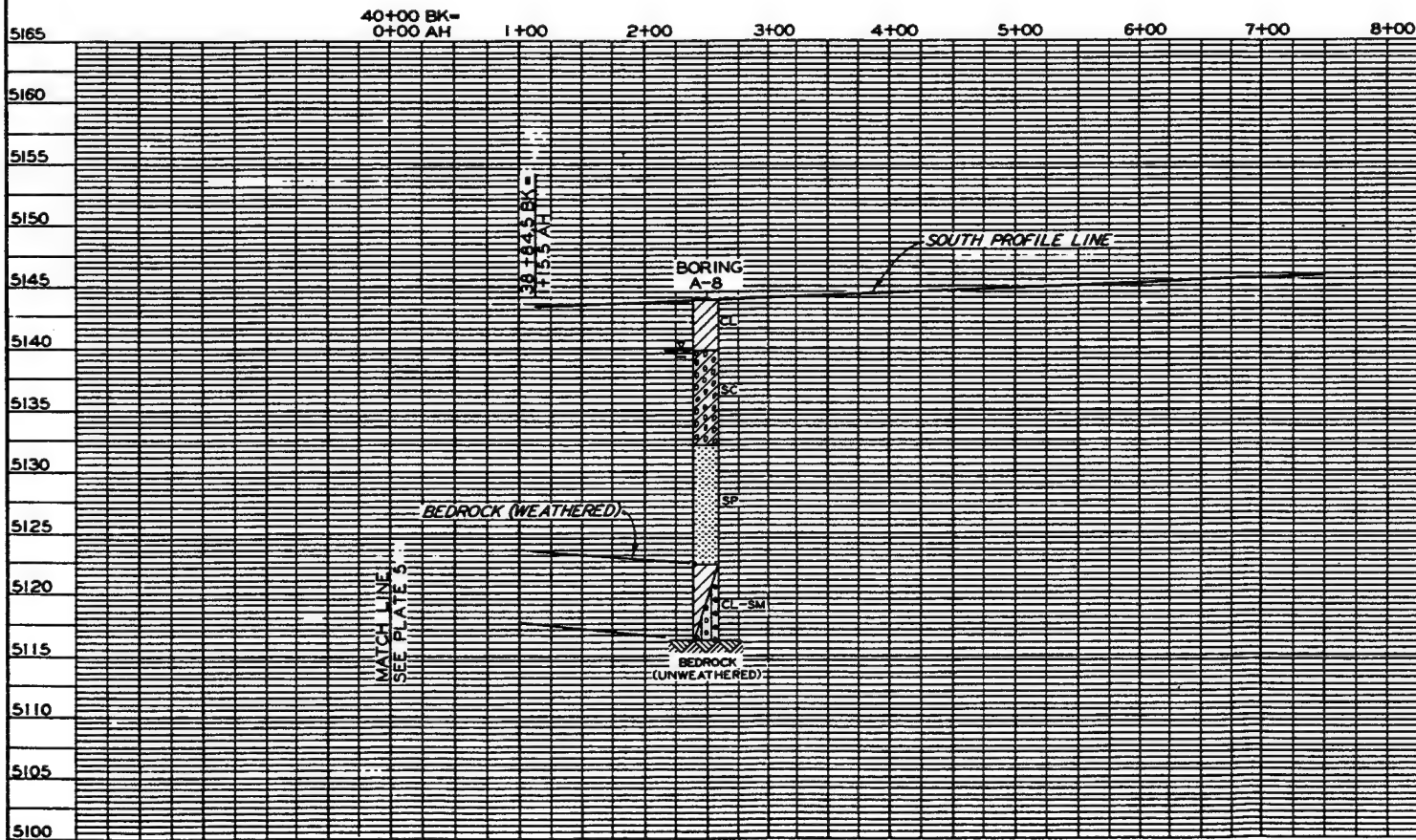
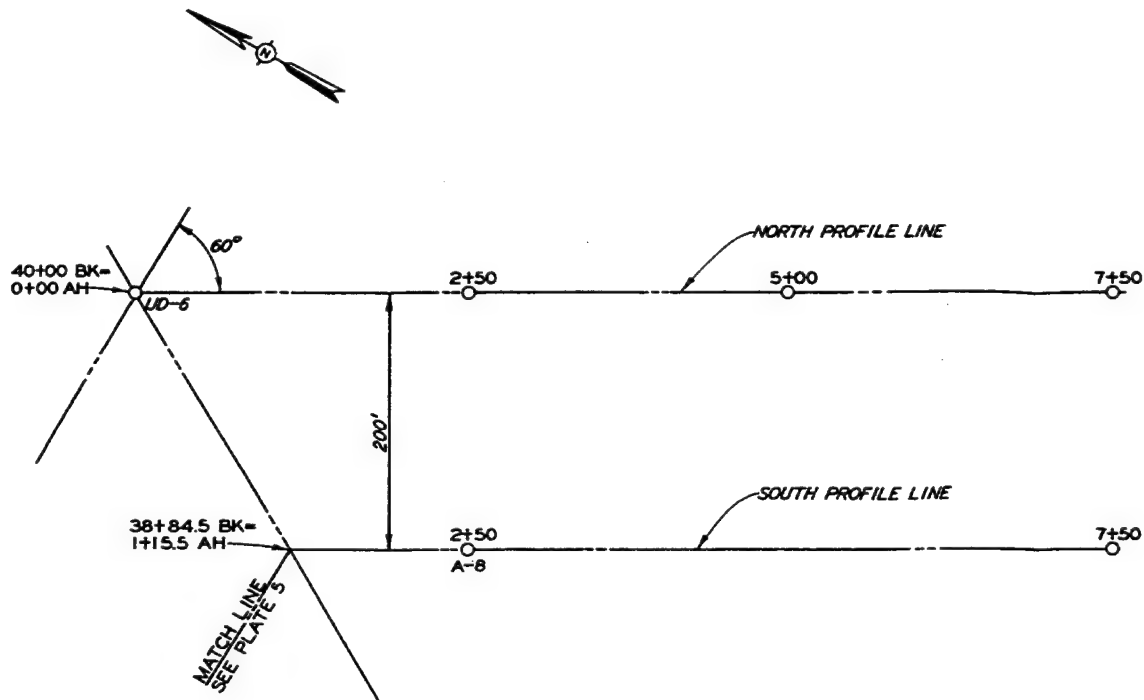
PLAN AND SOIL PROFILE
INTERIM CONTAINMENT SYSTEM
NORTH ALIGNMENT
ROCKY MOUNTAIN ARSENAL











NORTH PROFILE LINE

5+00

7+50

SOUTH PROFILE LINE

7+50



5+00

6+00

7+00

8+00

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OUTH PROFILE LINE

PLAN AND SOIL PROFILE
INTERIM CONTAINMENT SYSTEM
SOUTH ALIGNMENT
ROCKY MOUNTAIN ARSENAL



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UD-2

UD-1

222

BOG

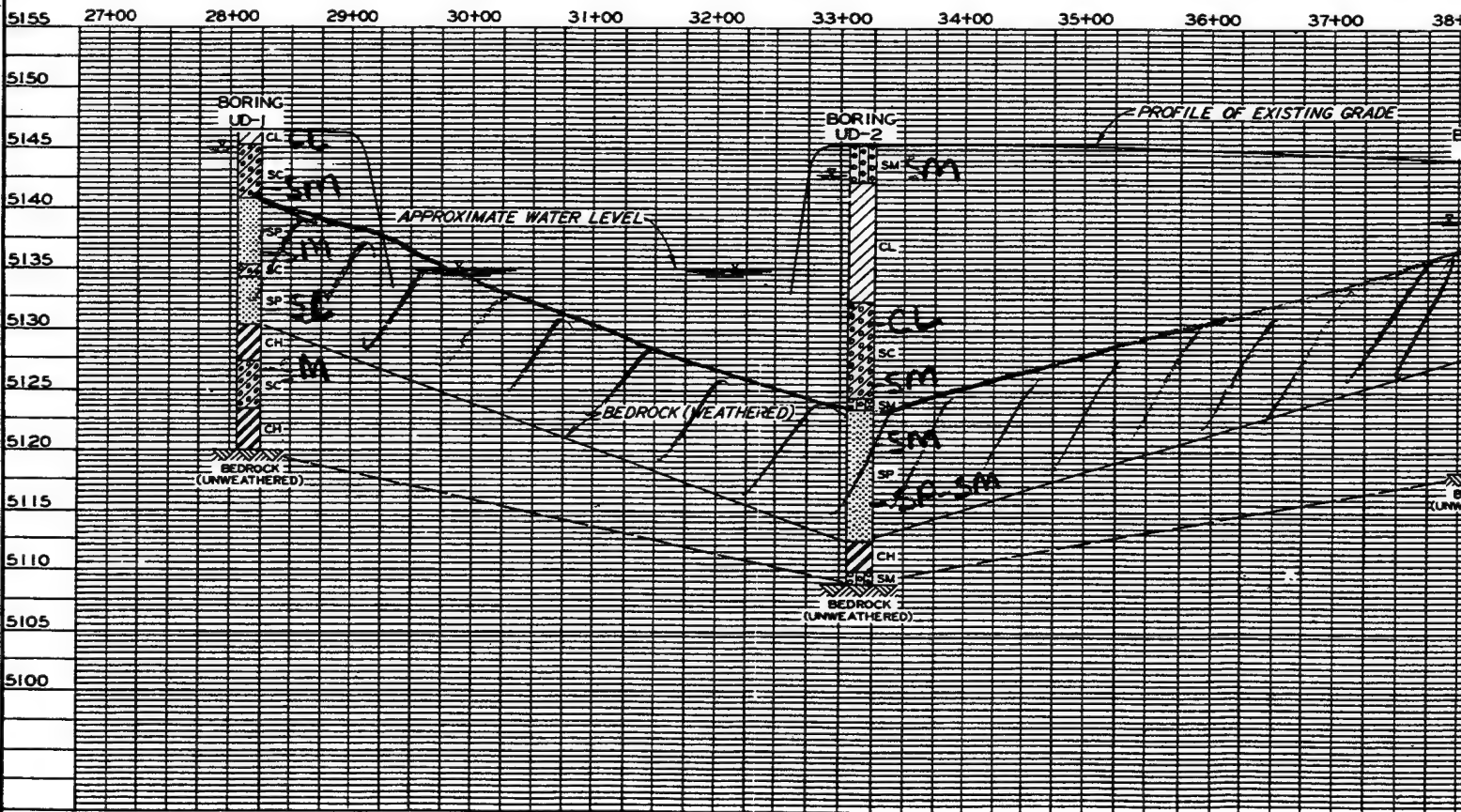
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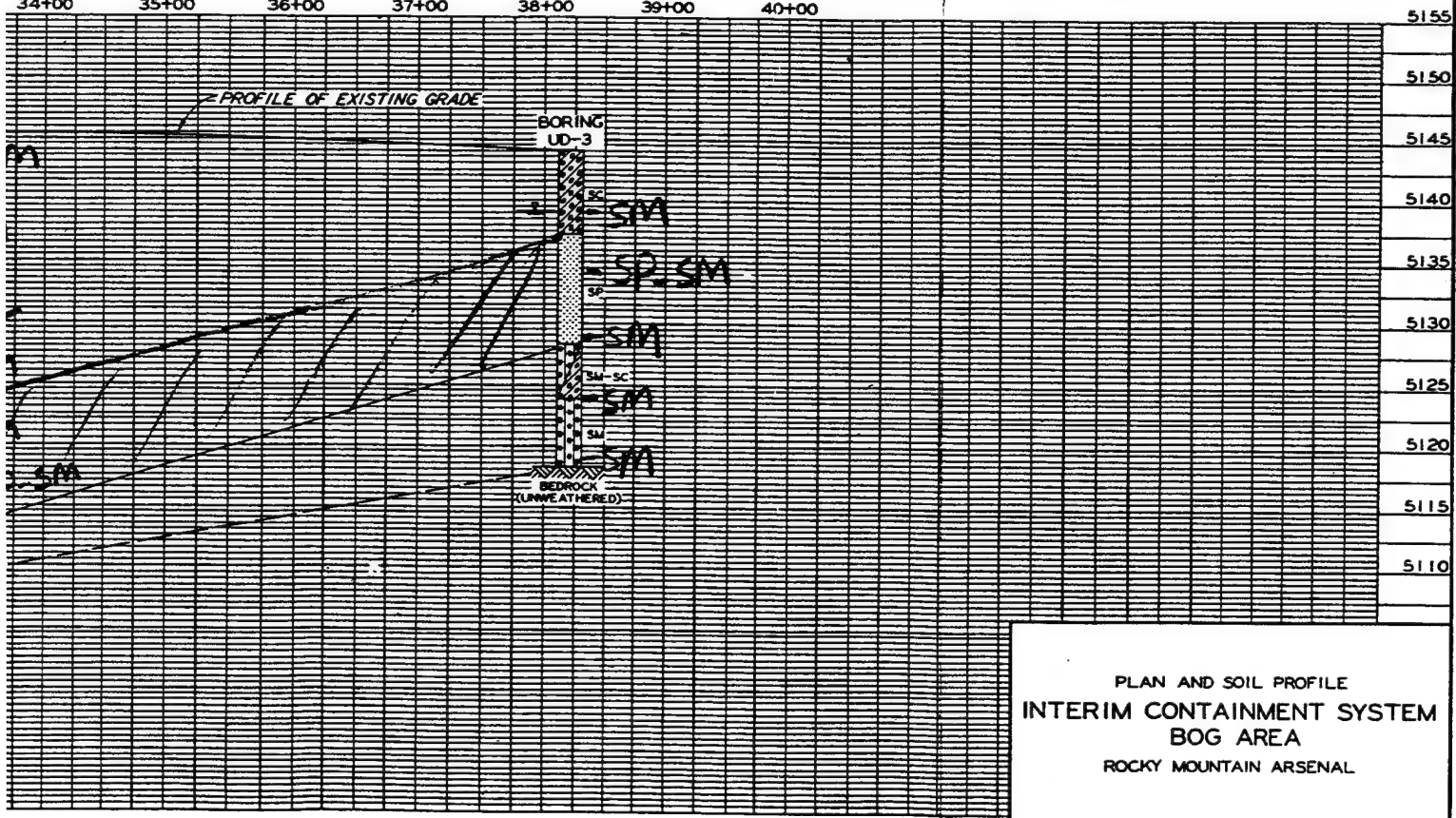
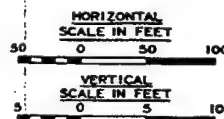
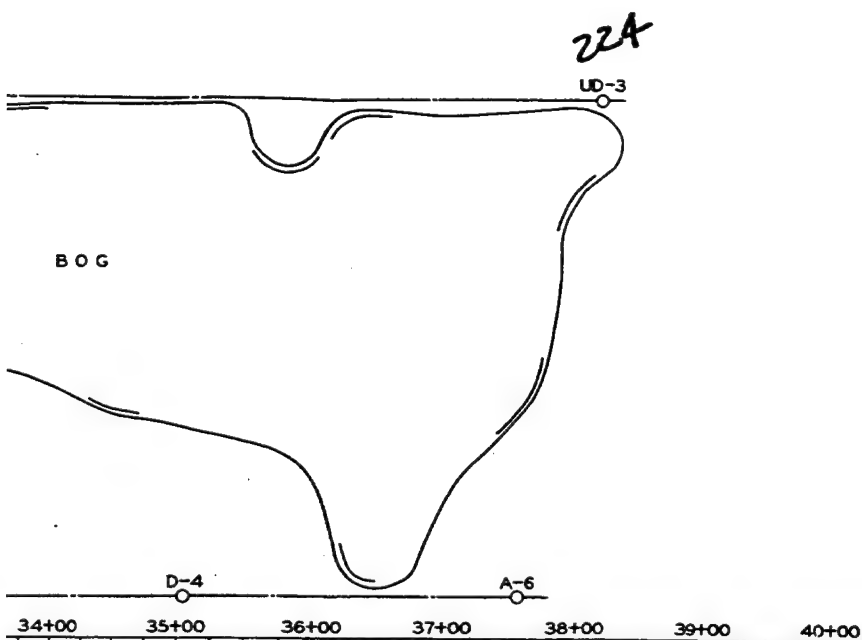
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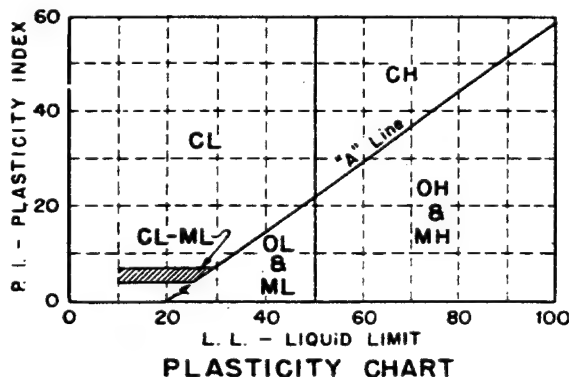
UNIFIED SOIL CLASSIFICATION

MAJOR DIVISION	TYPE	LETTER SYMBOL	SYM BOL	TYPICAL NAMES
COARSE - GRAINED SOILS More than half of material is larger than No. 200 sieve size	GRAVELS More than half of coarse fraction is larger than No. 4 sieve size	CLEAN GRAVEL (Little or No Fines)	GW	GRAVEL, Well Graded, gravel-sand mixtures, little or no fines
		GRAVEL WITH FINES (Appreciable Amount of Fines)	GP	GRAVEL, Poorly Graded, gravel-sand mixtures, little or no fines
		CLEAN SAND (Little or No Fines)	GM	SILTY GRAVEL, gravel-sand-silt mixtures
		SANDS WITH FINES (Appreciable Amount of Fines)	GC	CLAYEY GRAVEL, gravel-sand-clay mixtures
	SANDS More than half of coarse fraction is smaller than No. 4 sieve size	CLEAN SAND (Little or No Fines)	SW	SAND, Well - Graded, gravelly sands
		SANDS WITH FINES (Appreciable Amount of Fines)	SP	SAND, Poorly - Graded, gravelly sands
			SM	SILTY SAND, sand-silt mixtures
			SC	CLAYEY SAND, sand-clay mixtures
FINE - GRAINED SOILS More than half the material is smaller than No. 200 sieve size	SILTS AND CLAYS (Liquid Limit < 50)	ML		SILT & very fine sand, silty or clayey fine sand or clayey silt with slight plasticity
		CL		LEAN CLAY; Sandy Clay; Silty Clay; of low to medium plasticity
		OL		ORGANIC SILTS and organic silty clays of low plasticity
	SILTS AND CLAYS (Liquid Limit > 50)	MH		SILT, fine sandy or silty soil with high plasticity
		CH		FAT CLAY, inorganic clay of high plasticity
		OH		ORGANIC CLAYS of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS		Pt		PEAT, and other highly organic soil
WOOD		Wd		WOOD
SHELLS		SI		SHELLS
NO SAMPLE				

NOTE: Soils possessing characteristics of two groups are designated by combinations of group symbols

DESCRIPTIVE SYMBOLS

COLOR		CONSISTENCY FOR COHESIVE SOILS			MODIFICATIONS	
COLOR	SYMBOL	CONSISTENCY	COHESION IN LBS./SQ. FT. FROM UNCONFINED COMPRESSION TEST	SYMBOL	MODIFICATION	SYMBOL
TAN	T	VERY SOFT	< 250	vSo	Traces	Tr-
YELLOW	Y	SOFT	250 - 500	So	Fine	F
RED	R	MEDIUM	500 - 1000	M	Medium	M
BLACK	BK	STIFF	1000 - 2000	St	Coarse	C
GRAY	Gr	VERY STIFF	2000 - 4000	vSt	Concretions	cc
LIGHT GRAY	lGr	HARD	> 4000	H	Rootlets	rt
DARK GRAY	dGr				Lignite fragments	lg
BROWN	Br				Shale fragments	sh
LIGHT BROWN	lBr				Sandstone fragments	sds
DARK BROWN	dBr				Shell fragments	slf
BROWNISH-GRAY	br Gr				Organic matter	O
GRAYISH-BROWN	gyBr				Clay strata or lenses	CS
GREENISH-GRAY	gnGr				Silt strata or lenses	SIS
GRAYISH-GREEN	gyGn				Sand strata or lenses	SS
GREEN	Gn				Sandy	S
BLUE	Bl				Gravelly	G
BLUE-GREEN	BlGn				Boulders	B
WHITE	Wh				Slickensides	SL
MOTTLED	Mot				Wood	Wd
					Oxidized	Ox
					Crumbly	Cr
					Loose	Lo
					Vegetation	Veg

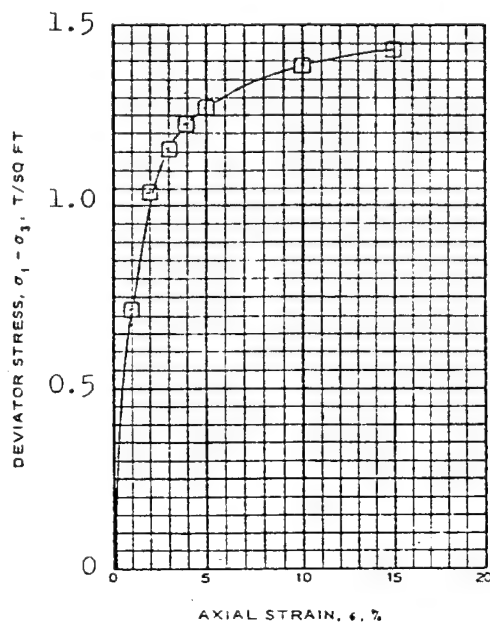
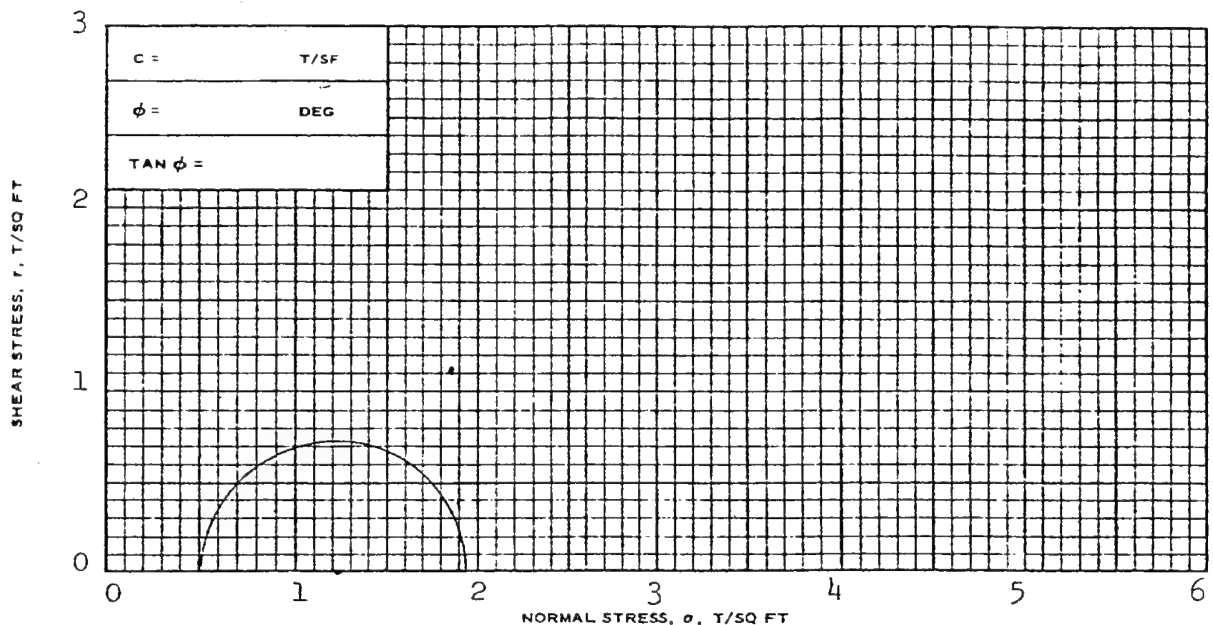


For classification of fine - grained soils

Table 1

Purpose of Groundwater Observation Wells

<u>Well Number - Figure 7</u>	<u>Purpose</u>
1, 3, 8, 16, 23, 27, 9, 17	Indicate incoming groundwater quality and quantity
4, 9, 17, 24, 10, 18	Indicate groundwater levels around dewatering system used to establish pumping rates
1, 2, 27, 28	Indicate influence of interim containment system on groundwater outside of the local area of the system
10, 18, 11, 15, 19	Indicate groundwater levels on each side of barrier and effectiveness of barrier
wells north of bog	Indicate recharge rate and effect of recharge on water quality
north-south lines of wells	Readings for groundwater level cross sections
all wells	Readings used for groundwater level and quality contour maps

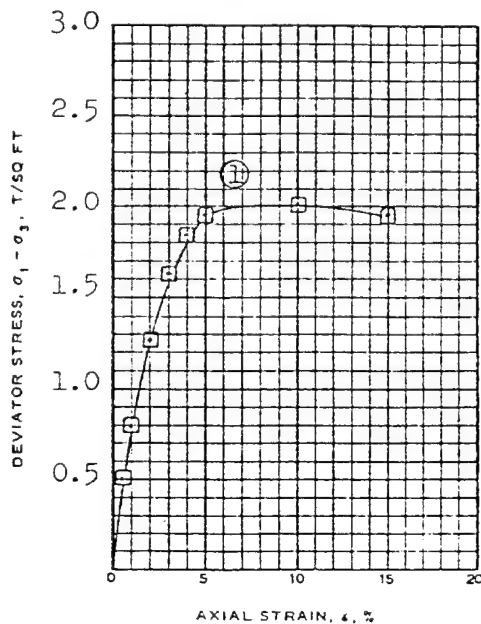
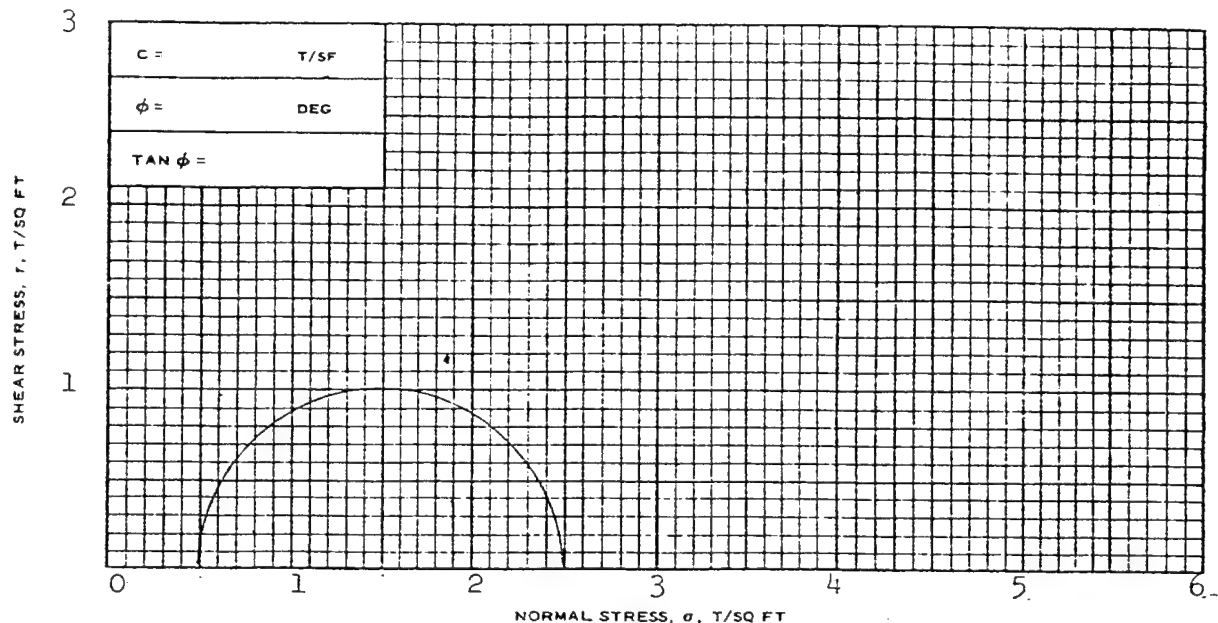


SPECIMEN NO.		1			
INITIAL	WATER CONTENT, %	w_o	19.1		
	DRY DENSITY LB/ CU FT	γ_d	99.4		
	SATURATION, %	s_o	58.8		
	VOID RATIO	e_o	0.877		
BEFORE SHEAR	WATER CONTENT, %	w_c			
	DRY DENSITY LB/ CU FT	γ_{dc}			
	SATURATION, %	s_c			
	VOID RATIO	e_c			
FINAL BACK PRESSURE, T/SQ FT		u_o			
MINOR PRINCIPAL STRESS, T/SQ FT		σ_3	0.5		
MAXIMUM DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{MAX}$	1.43		
TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN		t_f	37		
ULTIMATE DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{ULT}$			
INITIAL DIAMETER, IN.		D_o	1.40		
INITIAL HEIGHT, IN.		H_o	3.00		

CONTROLLED- STRAIN TEST

DESCRIPTION OF SPECIMENS LEAN CLAY(CL), brown, with fine sand

LL 36	PL 16	PI 20	G _s 2.70	TYPE OF SPECIMEN	UNDISTURBED	TYPE OF TEST	Q
REMARKS: Soil too friable to permit trimming more specimens.				PROJECT ROCKY MOUNTAIN ARSENAL			
				BORING NO. UD-2			
				SAMPLE NO. 2			
				DEPTH/ELEV			
				LABORATORY USAEWES		DATE 1 Sept., 1976	
				KOC TRIAXIAL COMPRESSION TEST REPORT			



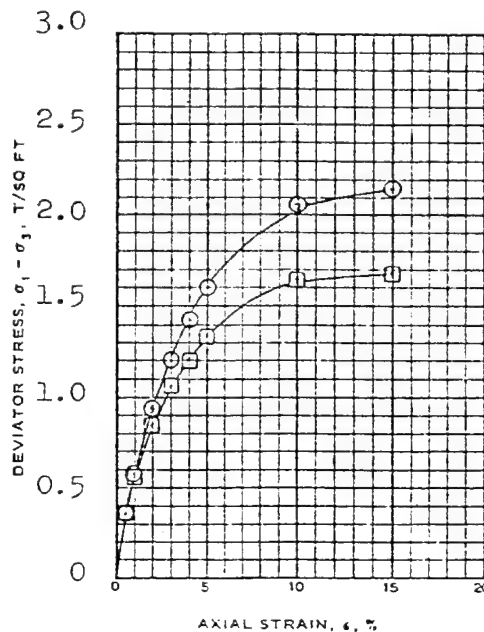
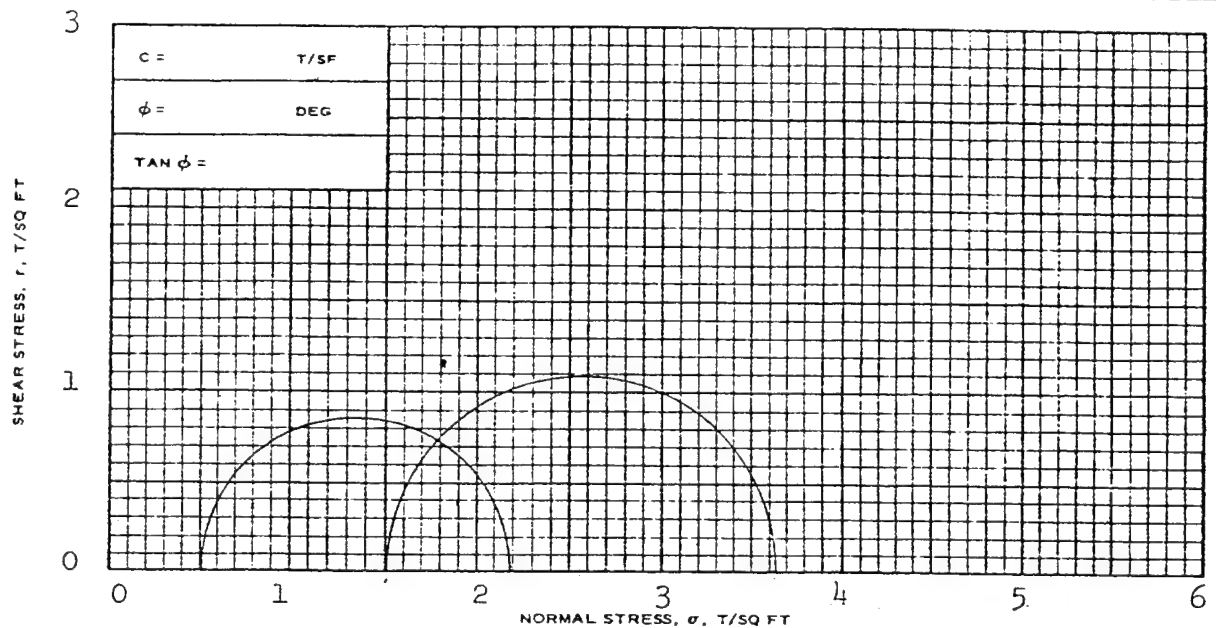
SPECIMEN NO.		1	2		
INITIAL	WATER CONTENT, %	w_o	14.5	11.4	
	DRY DENSITY LB/ CU FT	γ_d	100.3	116.7	
	SATURATION, %	s_o	56.9	68.1	
	VOID RATIO	e_o	0.693	0.455	
BEFORE SHEAR	WATER CONTENT, %	w_c			
	DRY DENSITY LB/ CU FT	γ_{dc}			
	SATURATION, %	s_c			
	VOID RATIO	e_c			
	FINAL BACK PRESSURE, T/SQ FT	u_o			
MINOR PRINCIPAL STRESS, T/SQ FT		σ_3	0.5	1.5	
MAXIMUM DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{MAX}$	2.00	8.8+	
TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN		t_f	21		
ULTIMATE DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{ULT}$			
INITIAL DIAMETER, IN.		D_o	1.40	1.41	
INITIAL HEIGHT, IN.		H_o	3.00	3.00	

CONTROLLED- STRAIN

TEST

DESCRIPTION OF SPECIMENS SANDY CLAY(CL), brown

LL 29	PL 14	PI 15	Gs 2.72	TYPE OF SPECIMEN	UNDISTURBED	TYPE OF TEST	Q
REMARKS: Specimen 2 exceeded capacity of testing machine without failing. Insufficient sample for trimming additional specimens.				PROJECT			ROCKY MOUNTAIN ARSENAL
				BORING NO.	UD-3	SAMPLE NO.	1
				DEPTH/ELEV			
				LABORATORY	USAEWES	DATE	13 Sept., 1976
				KOC TRIAXIAL COMPRESSION TEST REPORT			

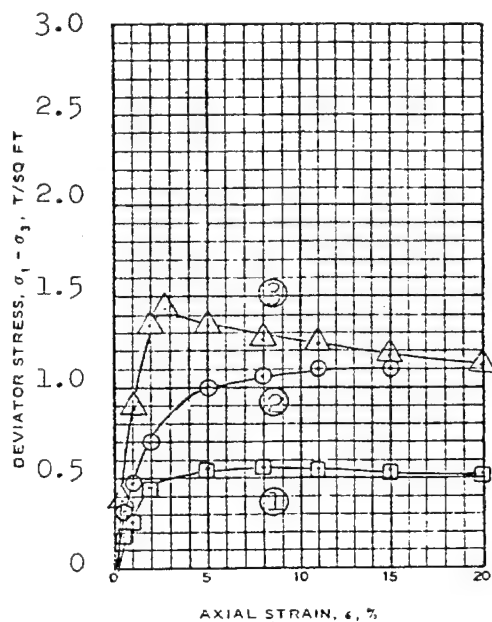
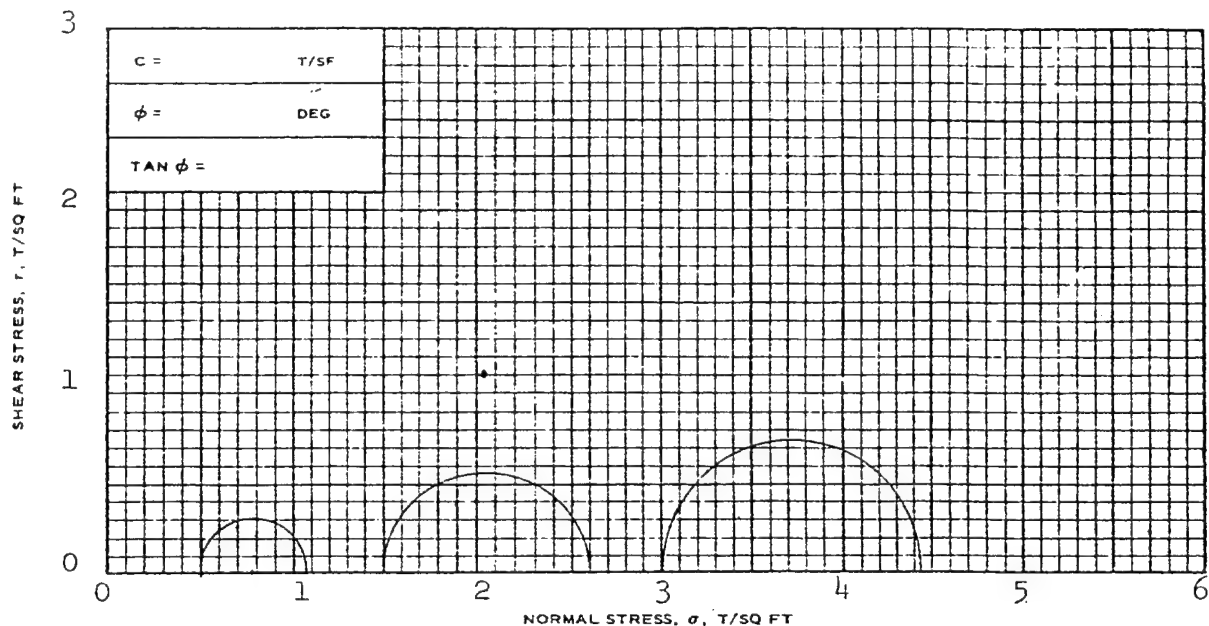


SPECIMEN NO.		1	2		
INITIAL	WATER CONTENT, %	w_o	15.5	15.9	
	DRY DENSITY LB/CU FT	γ_{d_o}	114.0	110.0	
	SATURATION, %	s_o	88.2	81.2	
	VOID RATIO	e_o	0.473	0.527	
BEFORE SHEAR	WATER CONTENT, %	w_c			
	DRY DENSITY LB/CU FT	γ_{d_c}			
	SATURATION, %	s_c			
	VOID RATIO	e_c			
	FINAL BACK PRESSURE, T/SQ FT	u_o			
	MINOR PRINCIPAL STRESS, T/SQ FT	σ_3	0.5	1.5	
	MAXIMUM DEVIATOR STRESS, T/SQ FT	$(\sigma_1 - \sigma_3)_{MAX}$	1.68	2.13	
	TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN	t_f	32	32	
	ULTIMATE DEVIATOR STRESS, T/SQ FT	$(\sigma_1 - \sigma_3)_{ULT}$			
	INITIAL DIAMETER, IN.	D_o	1.40	1.40	
CONTROLLED- STRAIN TEST	INITIAL HEIGHT, IN.	H_o	3.00	3.00	

DESCRIPTION OF SPECIMENS SANDY SILT(ML).brown

LL 20	PL 17	PI 3	G _s 2.69	TYPE OF SPECIMEN UNDISTURBED	TYPE OF TEST Q
REMARKS: Soil too friable to permit trimming more test specimens.				PROJECT ROCKY MOUNTAIN ARSENAL	
				BORING NO. UD-3	SAMPLE NO. 2
				DEPTH/ELEV	
				LABORATORY USAEWES	DATE 14 Sept.. 1976
KOC TRIAXIAL COMPRESSION TEST REPORT					

3 2 1 0	<div style="display: flex; justify-content: space-between; border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <div>$c =$ T/SF</div> <div>$\phi =$ DEG</div> <div>TAN $\phi =$</div> </div>																																																																									
2.0 1.5 1.0 0.5 0																																																																										
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="2" style="text-align: center;">SPECIMEN NO.</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> <td style="text-align: center;">3</td> </tr> <tr> <td rowspan="4" style="text-align: center; vertical-align: middle;">INITIAL</td> <td>WATER CONTENT, %</td> <td>w_o 18.7</td> <td>18.0</td> <td>18.9</td> </tr> <tr> <td>DRY DENSITY LB/CU FT</td> <td>γ_d 102.7</td> <td>101.2</td> <td>95.3</td> </tr> <tr> <td>SATURATION, %</td> <td>s_o 78.3</td> <td>72.6</td> <td>66.1</td> </tr> <tr> <td>VOID RATIO</td> <td>e_o 0.647</td> <td>0.672</td> <td>0.775</td> </tr> <tr> <td rowspan="5" style="text-align: center; vertical-align: middle;">BEFORE SHEAR</td> <td>WATER CONTENT, %</td> <td>w_c</td> <td></td> <td></td> </tr> <tr> <td>DRY DENSITY LB/CU FT</td> <td>γ_{dc}</td> <td></td> <td></td> </tr> <tr> <td>SATURATION, %</td> <td>s_c</td> <td></td> <td></td> </tr> <tr> <td>VOID RATIO</td> <td>e_c</td> <td></td> <td></td> </tr> <tr> <td>FINAL BACK PRESSURE, T/SQ FT</td> <td>u_o</td> <td></td> <td></td> </tr> <tr> <td colspan="2">MINOR PRINCIPAL STRESS, T/SQ FT</td> <td>σ_3 0.5</td> <td>1.5</td> <td>3.0</td> </tr> <tr> <td colspan="2">MAXIMUM DEVIATOR STRESS, T/SQ FT</td> <td>$(\sigma_1 - \sigma_3)_{MAX}$ 1.17</td> <td>1.51</td> <td>2.19</td> </tr> <tr> <td colspan="2">TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN</td> <td>$t_f$ 30</td> <td>32</td> <td>20</td> </tr> <tr> <td colspan="2">ULTIMATE DEVIATOR STRESS, T/SQ FT</td> <td>$(\sigma_1 - \sigma_3)_{ULT}$</td> <td></td> <td></td> </tr> <tr> <td colspan="2">INITIAL DIAMETER, IN.</td> <td>D_o 1.40</td> <td>1.41</td> <td>1.39</td> </tr> <tr> <td colspan="2">INITIAL HEIGHT, IN.</td> <td>H_o 3.00</td> <td>3.00</td> <td>3.00</td> </tr> </table>		SPECIMEN NO.		1	2	3	INITIAL	WATER CONTENT, %	w_o 18.7	18.0	18.9	DRY DENSITY LB/CU FT	γ_d 102.7	101.2	95.3	SATURATION, %	s_o 78.3	72.6	66.1	VOID RATIO	e_o 0.647	0.672	0.775	BEFORE SHEAR	WATER CONTENT, %	w_c			DRY DENSITY LB/CU FT	γ_{dc}			SATURATION, %	s_c			VOID RATIO	e_c			FINAL BACK PRESSURE, T/SQ FT	u_o			MINOR PRINCIPAL STRESS, T/SQ FT		σ_3 0.5	1.5	3.0	MAXIMUM DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{MAX}$ 1.17	1.51	2.19	TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN		t_f 30	32	20	ULTIMATE DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{ULT}$			INITIAL DIAMETER, IN.		D_o 1.40	1.41	1.39	INITIAL HEIGHT, IN.		H_o 3.00	3.00	3.00
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INITIAL HEIGHT, IN.		H_o 3.00	3.00	3.00																																																																						
CONTROLLED- STRAIN TEST																																																																										
DESCRIPTION OF SPECIMENS SANDY, SILTY CLAY(CL), yellow																																																																										
LL 39 PL 23 PI 16 G_s 2.71	TYPE OF SPECIMEN UNDISTURBED TYPE OF TEST C																																																																									
REMARKS:	PROJECT ROCKY MOUNTAIN ARSENAL																																																																									
	BORING NO. UD-4 SAMPLE NO. 2																																																																									
	DEPTH/ELEV 5.0-7.0																																																																									
	LABORATORY USAEWES DATE 16 August, 1976																																																																									
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SPECIMEN NO.			1	2	3	
INITIAL	WATER CONTENT, %	w_o	22.0	23.7	24.3	
	DRY DENSITY LB/ CU FT	γ_d	88.2	98.4	95.6	
	SATURATION, %	s_o	65.5	90.2	86.4	
	VOID RATIO	e_o	0.904	0.707	0.757	
BEFORE SHEAR	WATER CONTENT, %	w_c				
	DRY DENSITY LB/CU FT	γ_{dc}				
	SATURATION, %	s_c				
	VOID RATIO	e_c				
	FINAL BACK PRESSURE, T/SQ FT	u_o				
	MINOR PRINCIPAL STRESS, T/SQ FT	σ_3	0.5	1.5	3.0	
MAXIMUM DEVIATOR STRESS, T/SQ FT	$(\sigma_1 - \sigma_3)_{MAX}$	0.56	1.10	1.42		
TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN	t_f	13	20	7		
ULTIMATE DEVIATOR STRESS, T/SQ FT	$(\sigma_1 - \sigma_3)_{ULT}$					
INITIAL DIAMETER, IN.	d_o	1.43	1.39	1.43		
INITIAL HEIGHT, IN.	h_o					

CONTROLLED- STRAIN TEST

DESCRIPTION OF SPECIMENS SANDY CLAY (CL), brown

LL 34 PL 15 PI 19 G_s 2.69

TYPE OF SPECIMEN UNDISTURBED TYPE OF TEST Q

REMARKS:

PROJECT ROCKY MOUNTAIN ARSENAL

BORING NO. UD-5 SAMPLE NO. 2

DEPTH/ELEV 5.0-7.5

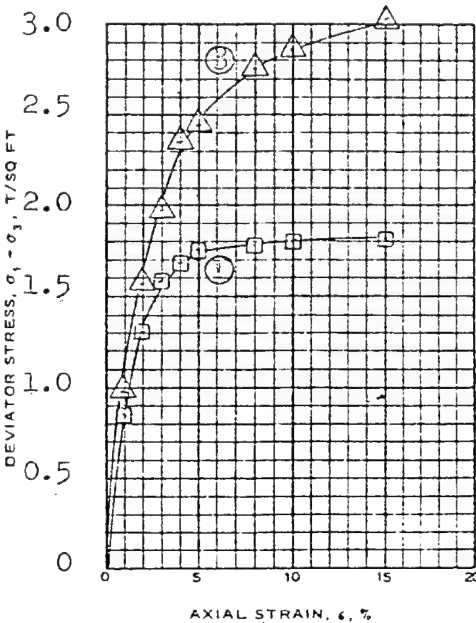
LABORATORY USAEWES DATE 16 August, 1976

JMS TRIAXIAL COMPRESSION TEST REPORT

3 2 1 0	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> C = T/SF ϕ = DEG TAN ϕ = </div> <div style="text-align: center; margin-top: 10px;"> NORMAL STRESS, σ, T/SQ FT </div>
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<div style="text-align: center;"> </div> <div style="text-align: center; margin-top: 10px;"> AXIAL STRAIN, ϵ, % </div>	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="2">SPECIMEN NO.</td> <td style="text-align: center;">2</td> </tr> <tr> <td rowspan="4" style="writing-mode: vertical-rl; transform: rotate(180deg);">INITIAL</td> <td>WATER CONTENT, %</td> <td style="text-align: center;">w_o 17.0</td> </tr> <tr> <td>DRY DENSITY LB./CU FT</td> <td style="text-align: center;">γ_{d_o} 79.1</td> </tr> <tr> <td>SATURATION, %</td> <td style="text-align: center;">s_o 40.6</td> </tr> <tr> <td>VOID RATIO</td> <td style="text-align: center;">e_o 1.13</td> </tr> <tr> <td rowspan="4" style="writing-mode: vertical-rl; transform: rotate(180deg);">BEFORE SHEAR</td> <td>WATER CONTENT, %</td> <td style="text-align: center;">w_c</td> </tr> <tr> <td>DRY DENSITY LB./CU FT</td> <td style="text-align: center;">γ_{d_c}</td> </tr> <tr> <td>SATURATION, %</td> <td style="text-align: center;">s_c</td> </tr> <tr> <td>VOID RATIO</td> <td style="text-align: center;">e_c</td> </tr> <tr> <td colspan="2">FINAL BACK PRESSURE, T/SQ FT</td> <td style="text-align: center;">u_o</td> </tr> <tr> <td colspan="2">MINOR PRINCIPAL STRESS, T/SQ FT</td> <td style="text-align: center;">σ_3 1.5</td> </tr> <tr> <td colspan="2">MAXIMUM DEVIATOR STRESS, T/SQ FT</td> <td style="text-align: center;">$(\sigma_1 - \sigma_3)_{MAX}$ 1.76</td> </tr> <tr> <td colspan="2">TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN</td> <td style="text-align: center;">t_f 36</td> </tr> <tr> <td colspan="2">ULTIMATE DEVIATOR STRESS, T/SQ FT</td> <td style="text-align: center;">$(\sigma_1 - \sigma_3)_{ULT}$</td> </tr> <tr> <td colspan="2">INITIAL DIAMETER, IN.</td> <td style="text-align: center;">D_o 1.38</td> </tr> <tr> <td colspan="2">INITIAL HEIGHT, IN.</td> <td style="text-align: center;">H_o 3.00</td> </tr> </table>	SPECIMEN NO.		2	INITIAL	WATER CONTENT, %	w_o 17.0	DRY DENSITY LB./CU FT	γ_{d_o} 79.1	SATURATION, %	s_o 40.6	VOID RATIO	e_o 1.13	BEFORE SHEAR	WATER CONTENT, %	w_c	DRY DENSITY LB./CU FT	γ_{d_c}	SATURATION, %	s_c	VOID RATIO	e_c	FINAL BACK PRESSURE, T/SQ FT		u_o	MINOR PRINCIPAL STRESS, T/SQ FT		σ_3 1.5	MAXIMUM DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{MAX}$ 1.76	TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN		t_f 36	ULTIMATE DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{ULT}$	INITIAL DIAMETER, IN.		D_o 1.38	INITIAL HEIGHT, IN.		H_o 3.00
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INITIAL HEIGHT, IN.		H_o 3.00																																									

CONTROLLED- STRAIN TEST			
DESCRIPTION OF SPECIMENS SANDY CLAY(CL), light brown			
LL 29	PL 14	PI 15	G _s 2.70
REMARKS: Soil too friable to permit trimming more specimens.		TYPE OF SPECIMEN UNDISTURBED	
		TYPE OF TEST Q	
		PROJECT ROCKY MOUNTAIN ARSENAL	
		BORING NO. UD-7	SAMPLE NO. 3
		DEPTH/ELEV _m 10.0-12.5	
		LABORATORY USAEWES	DATE 13 August, 1976
KOC TRIAXIAL COMPRESSION TEST REPORT			

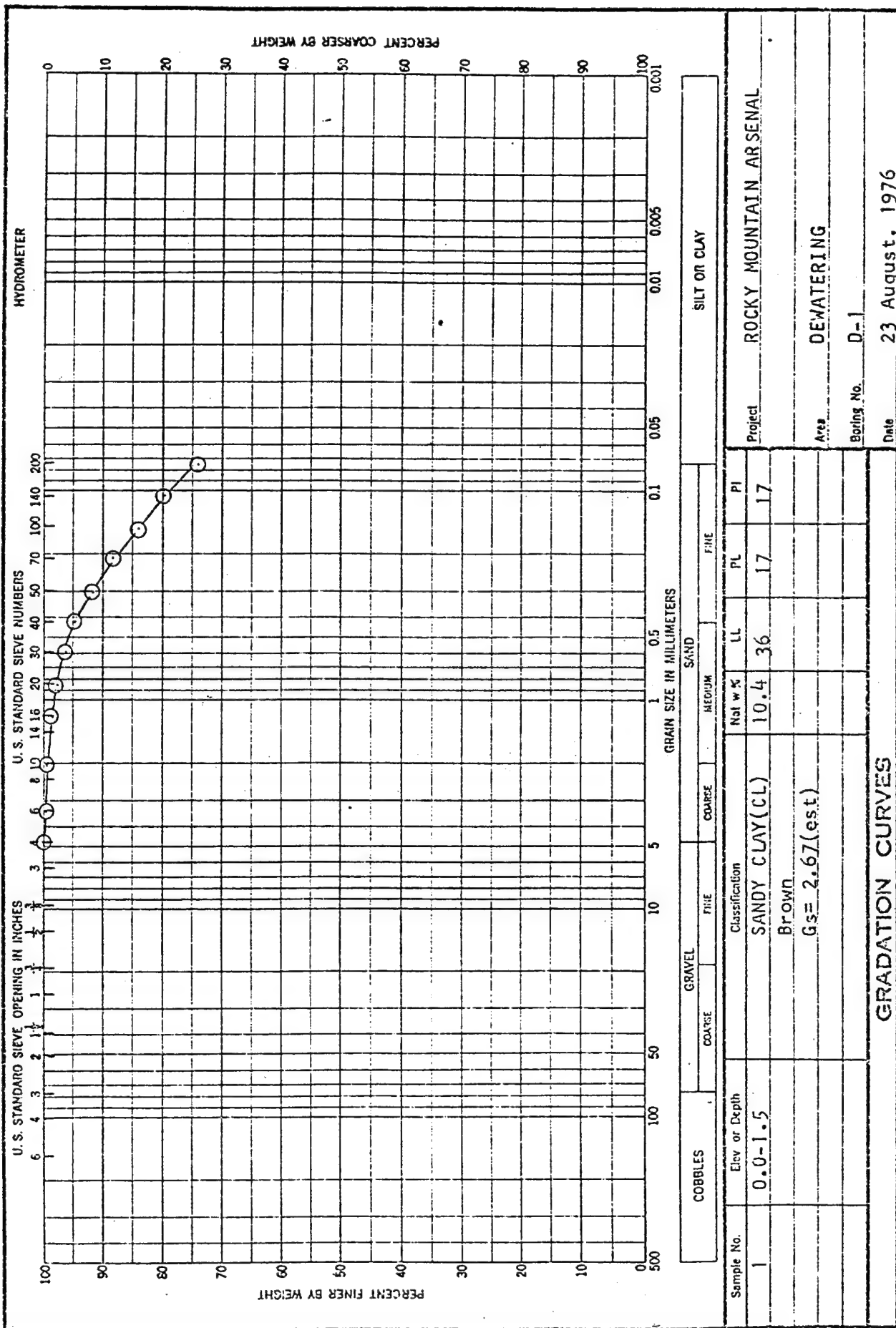


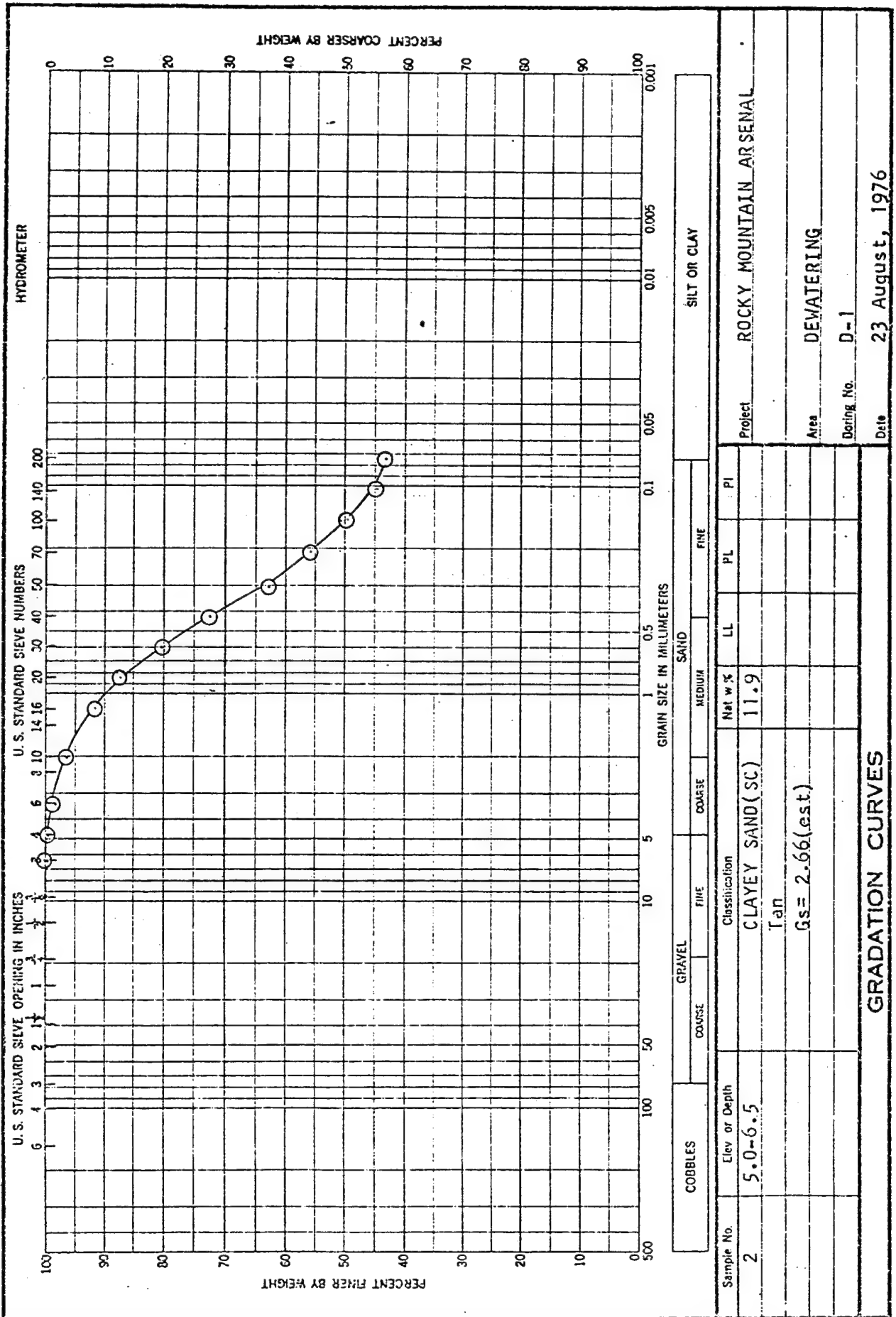
SPECIMEN NO.		1	3
AFTER	WATER CONTENT, %	w_o 18.7	19.2
	DRY DENSITY LB./CU FT	γ_d 102.3	101.7
	SATURATION, %	s_o 76.2	77.1
	VOID RATIO	e_o 0.672	0.682
BEFORE SHEAR	WATER CONTENT, %	w_c	
	DRY DENSITY LB./CU FT	γ_{dc}	
	SATURATION, %	s_c	
	VOID RATIO	e_c	
	FINAL BACK PRESSURE, T/SQ FT	u_o	
	MINOR PRINCIPAL STRESS, T/SQ FT	σ_3 0.5	3.0
MAXIMUM DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{MAX}$ 1.81	3.02
TIME TO $(\sigma_1 - \sigma_3)_{MAX}$, MIN		t_f 35	35
ULTIMATE DEVIATOR STRESS, T/SQ FT		$(\sigma_1 - \sigma_3)_{ULT}$	
INITIAL DIAMETER, IN.		D_o 1.40	1.41
INITIAL HEIGHT, IN.		H_o 3.00	3.00

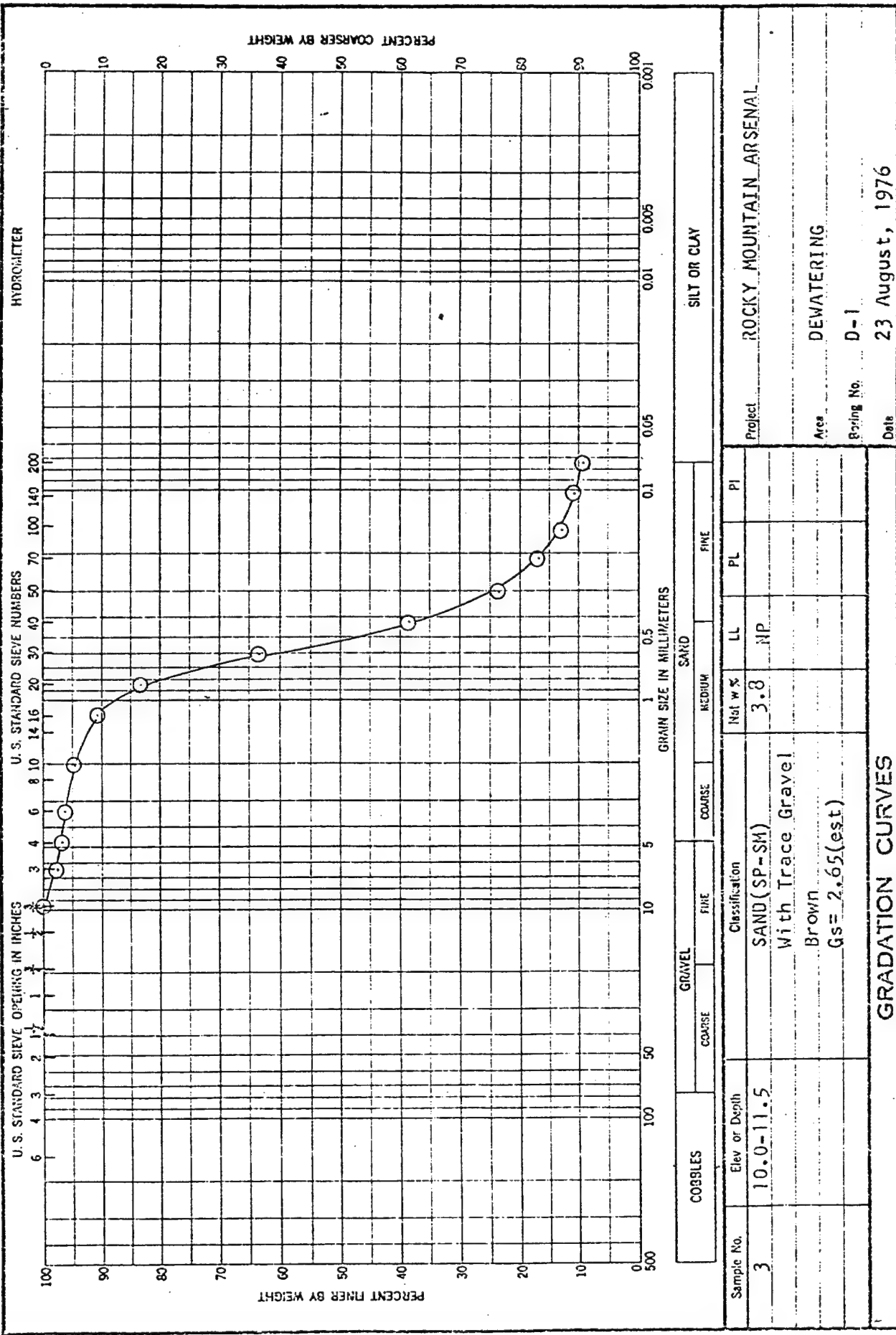
DESCRIPTION OF SPECIMENS LEAN CLAY (CL), brown, 1/8" diam. roots.

LL 42	PL 19	PI 23	G _s 2.74	TYPE OF SPECIMEN	UNDISTURBED	TYPE OF TEST	Q
REMARKS:				PROJECT			
				ROCKY MOUNTAIN ARSENAL			
				BORING NO.		SAMPLE NO.	
				UD-8		1	
				DEPTH/ELEV			
				LABORATORY		DATE	
				USAEWES		1 Sept., 1976	
				KOC TRIAXIAL COMPRESSION TEST REPORT			

3 2 1 0	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> C = T/SF φ = DEG TAN φ = </div>																																																											
3.0 2.5 2.0 1.5 1.0 0.5 0		<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="2">SPECIMEN NO.</td> <td>1</td> <td>3</td> </tr> <tr> <td rowspan="4" style="writing-mode: vertical-rl; transform: rotate(180deg);">INITIAL</td> <td>WATER CONTENT, %</td> <td>w_o 22.9</td> <td>25.2</td> </tr> <tr> <td>DRY DENSITY LB/ CU FT</td> <td>γ_d 103.6</td> <td>96.0</td> </tr> <tr> <td>SATURATION, %</td> <td>s_o 98.6</td> <td>90.1</td> </tr> <tr> <td>VOID RATIO</td> <td>e_o 0.627</td> <td>0.755</td> </tr> <tr> <td rowspan="4" style="writing-mode: vertical-rl; transform: rotate(180deg);">BEFORE SHEAR</td> <td>WATER CONTENT, %</td> <td>w_c</td> <td></td> </tr> <tr> <td>DRY DENSITY LB/ CU FT</td> <td>γ_d_c</td> <td></td> </tr> <tr> <td>SATURATION, %</td> <td>s_c</td> <td></td> </tr> <tr> <td>VOID RATIO</td> <td>e_c</td> <td></td> </tr> <tr> <td></td> <td>FINAL BACK PRESSURE, T/SQ FT</td> <td>u_o</td> <td></td> </tr> <tr> <td></td> <td>MINOR PRINCIPAL STRESS, T/SQ FT</td> <td>σ₃ 0.5</td> <td>3.0</td> </tr> <tr> <td></td> <td>MAXIMUM DEVIATOR STRESS, T/SQ FT</td> <td>(σ₁ - σ₃)_{MAX} 1.20</td> <td>0.94</td> </tr> <tr> <td></td> <td>TIME TO (σ₁ - σ₃)_{MAX}, MIN</td> <td>t_f 34</td> <td>38</td> </tr> <tr> <td></td> <td>ULTIMATE DEVIATOR STRESS, T/SQ FT</td> <td>(σ₁ - σ₃)_{ULT}</td> <td></td> </tr> <tr> <td></td> <td>INITIAL DIAMETER, IN.</td> <td>D_o 1.40</td> <td>1.40</td> </tr> <tr> <td></td> <td>INITIAL HEIGHT, IN.</td> <td>H_o 3.00</td> <td>3.00</td> </tr> </table>	SPECIMEN NO.		1	3	INITIAL	WATER CONTENT, %	w _o 22.9	25.2	DRY DENSITY LB/ CU FT	γ _d 103.6	96.0	SATURATION, %	s _o 98.6	90.1	VOID RATIO	e _o 0.627	0.755	BEFORE SHEAR	WATER CONTENT, %	w _c		DRY DENSITY LB/ CU FT	γ _d _c		SATURATION, %	s _c		VOID RATIO	e _c			FINAL BACK PRESSURE, T/SQ FT	u _o			MINOR PRINCIPAL STRESS, T/SQ FT	σ ₃ 0.5	3.0		MAXIMUM DEVIATOR STRESS, T/SQ FT	(σ ₁ - σ ₃) _{MAX} 1.20	0.94		TIME TO (σ ₁ - σ ₃) _{MAX} , MIN	t _f 34	38		ULTIMATE DEVIATOR STRESS, T/SQ FT	(σ ₁ - σ ₃) _{ULT}			INITIAL DIAMETER, IN.	D _o 1.40	1.40		INITIAL HEIGHT, IN.	H _o 3.00	3.00
SPECIMEN NO.		1	3																																																									
INITIAL	WATER CONTENT, %	w _o 22.9	25.2																																																									
	DRY DENSITY LB/ CU FT	γ _d 103.6	96.0																																																									
	SATURATION, %	s _o 98.6	90.1																																																									
	VOID RATIO	e _o 0.627	0.755																																																									
BEFORE SHEAR	WATER CONTENT, %	w _c																																																										
	DRY DENSITY LB/ CU FT	γ _d _c																																																										
	SATURATION, %	s _c																																																										
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	FINAL BACK PRESSURE, T/SQ FT	u _o																																																										
	MINOR PRINCIPAL STRESS, T/SQ FT	σ ₃ 0.5	3.0																																																									
	MAXIMUM DEVIATOR STRESS, T/SQ FT	(σ ₁ - σ ₃) _{MAX} 1.20	0.94																																																									
	TIME TO (σ ₁ - σ ₃) _{MAX} , MIN	t _f 34	38																																																									
	ULTIMATE DEVIATOR STRESS, T/SQ FT	(σ ₁ - σ ₃) _{ULT}																																																										
	INITIAL DIAMETER, IN.	D _o 1.40	1.40																																																									
	INITIAL HEIGHT, IN.	H _o 3.00	3.00																																																									
CONTROLLED- STRAIN TEST																																																												
DESCRIPTION OF SPECIMENS SANDY CLAY(CL), brown																																																												
LL 34	PL 15	PI 19	G _s 2.70	TYPE OF SPECIMEN UNDISTURBED	TYPE OF TEST Q																																																							
REMARKS:				PROJECT ROCKY MOUNTAIN ARSENAL																																																								
				BORING NO. UD-8	SAMPLE NO. 3																																																							
				DEPTH/ELEV																																																								
				LABORATORY USAEWES	DATE 13 Sept., 1976																																																							
KOC TRIAXIAL COMPRESSION TEST REPORT																																																												

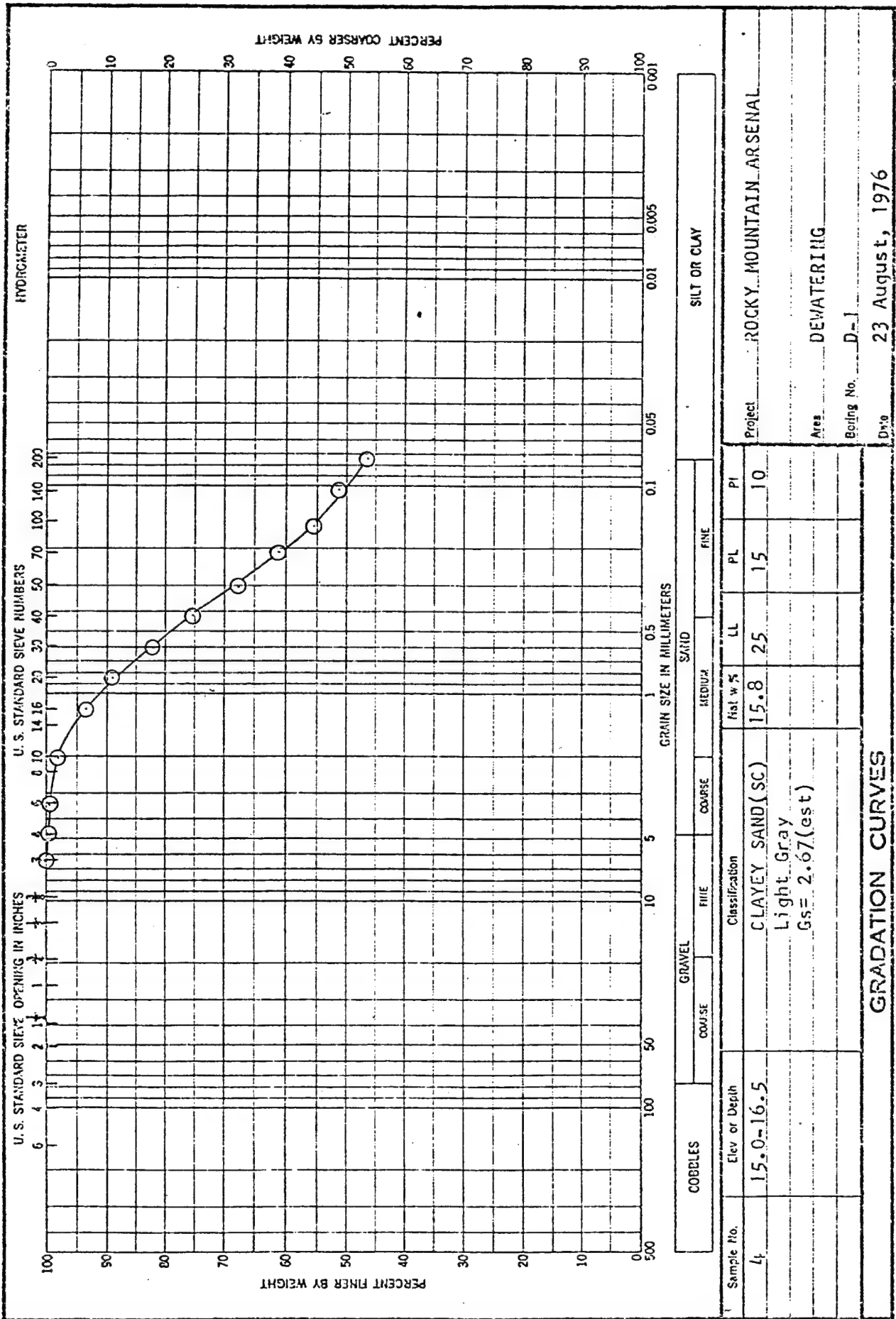


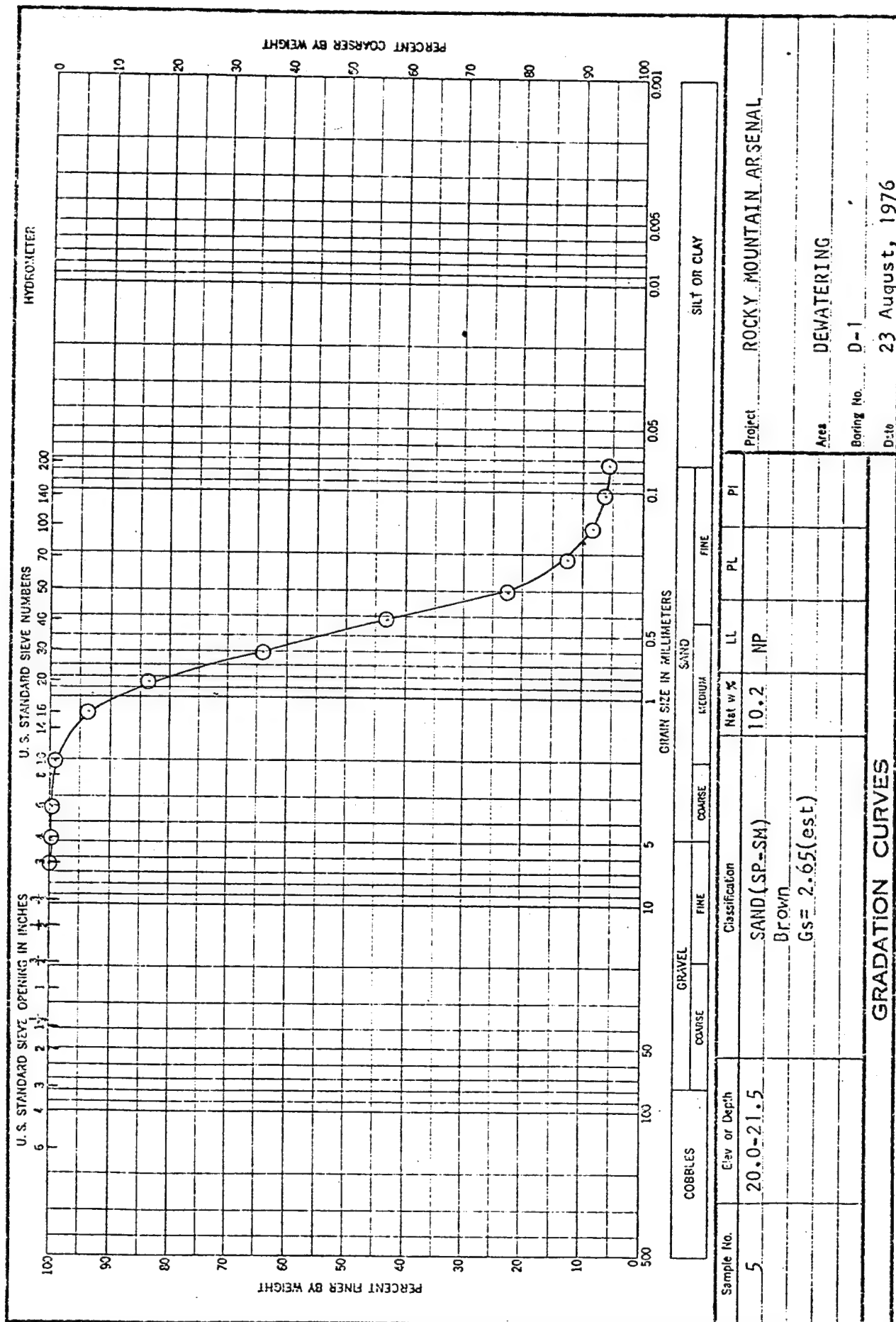




ENG FORM 2087
1 MAY 63

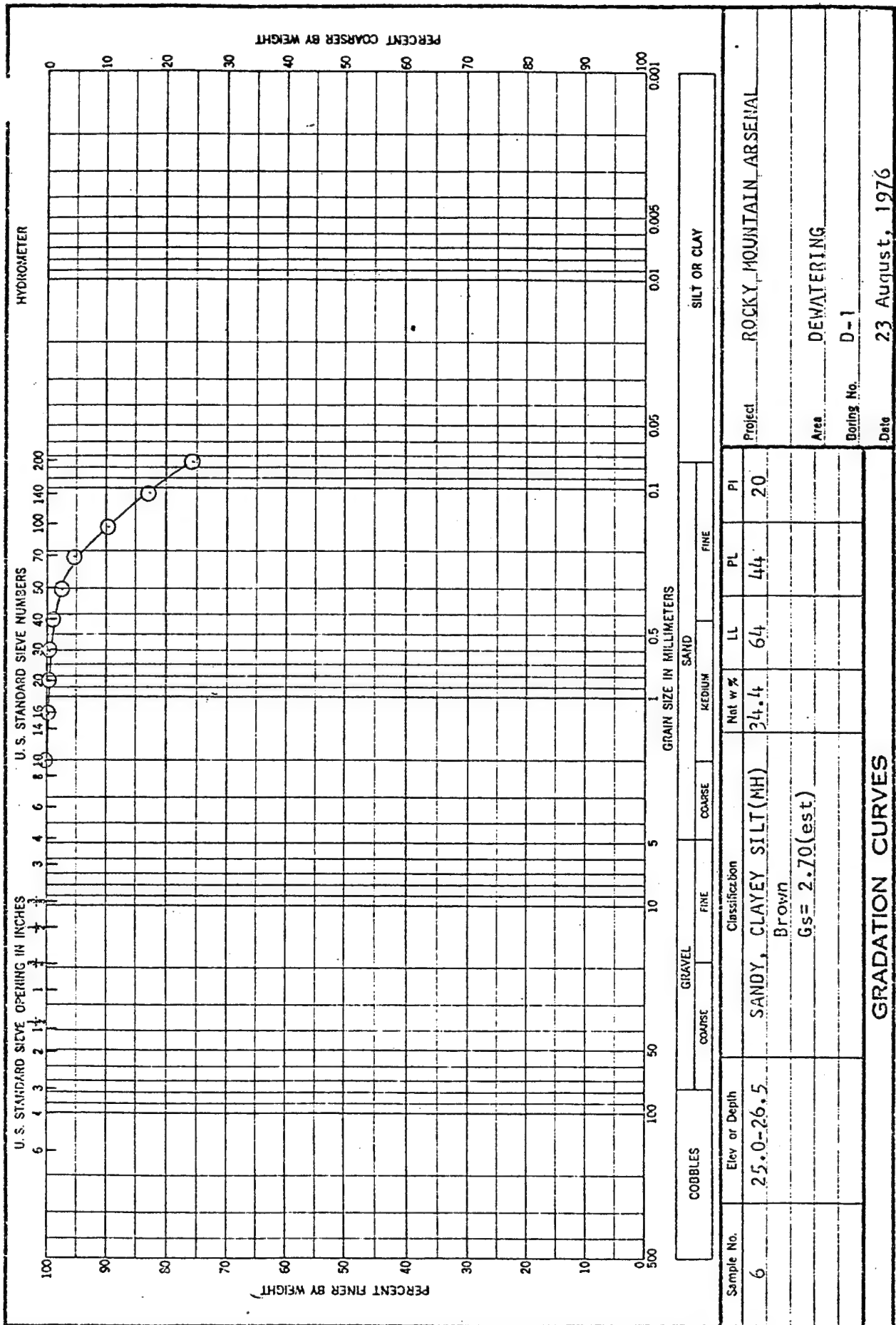
Ag. $D_{10} = 0.09$
-200 = 9%

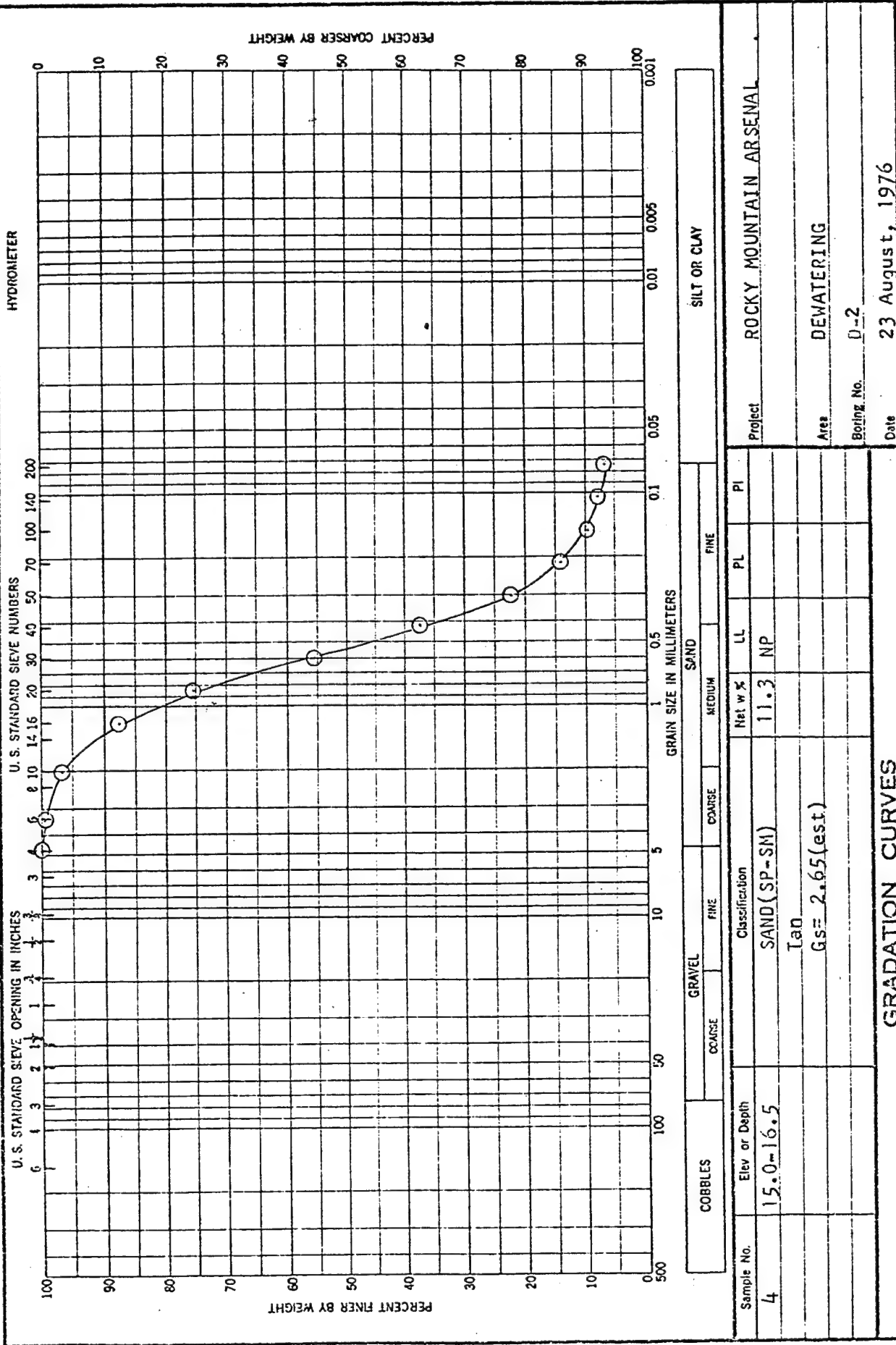




ENG FORM 2087
1 MAY 63

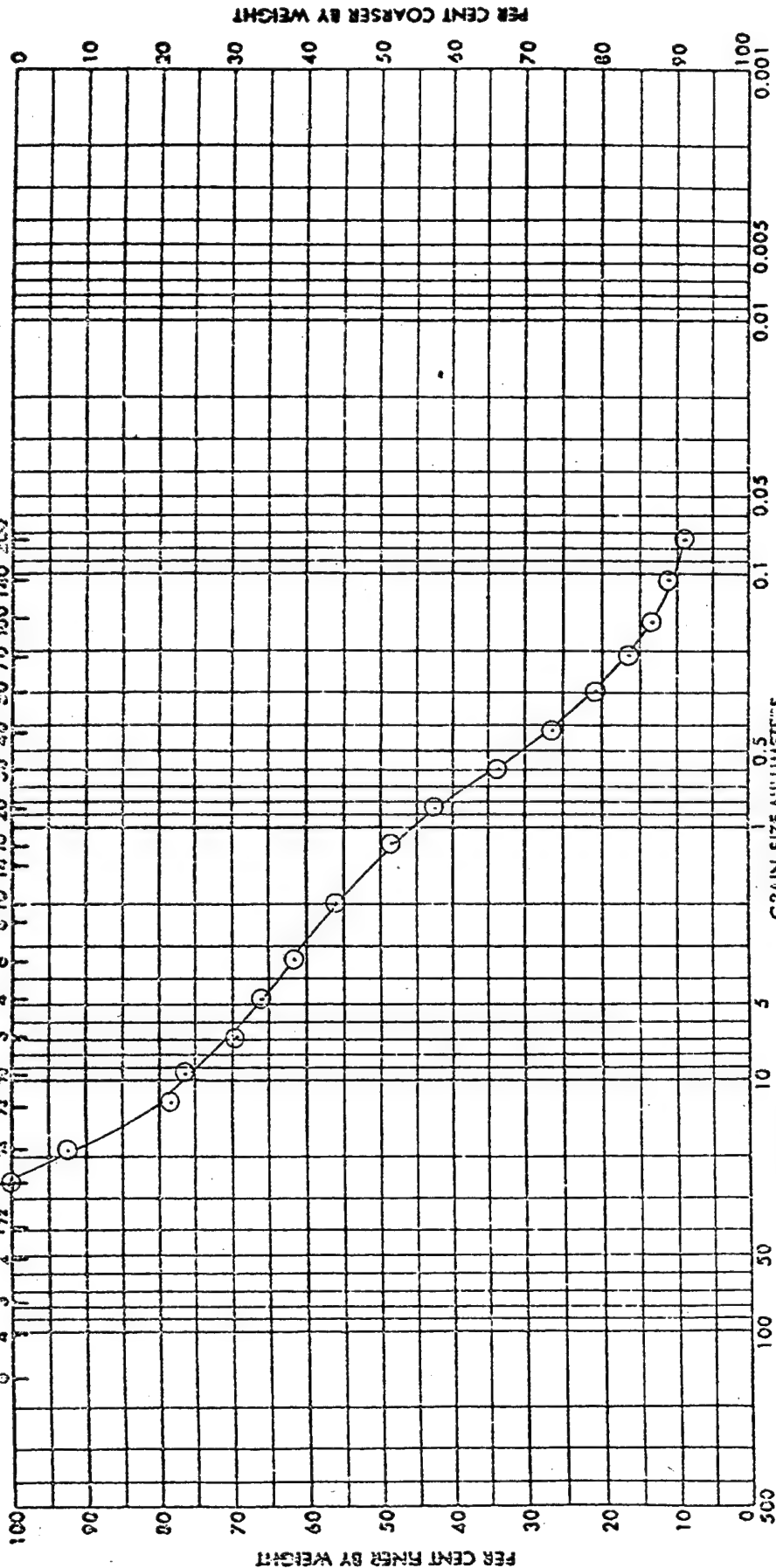
Ag $D_{50} = 0.18$
-200 = 62





HYDROMETER

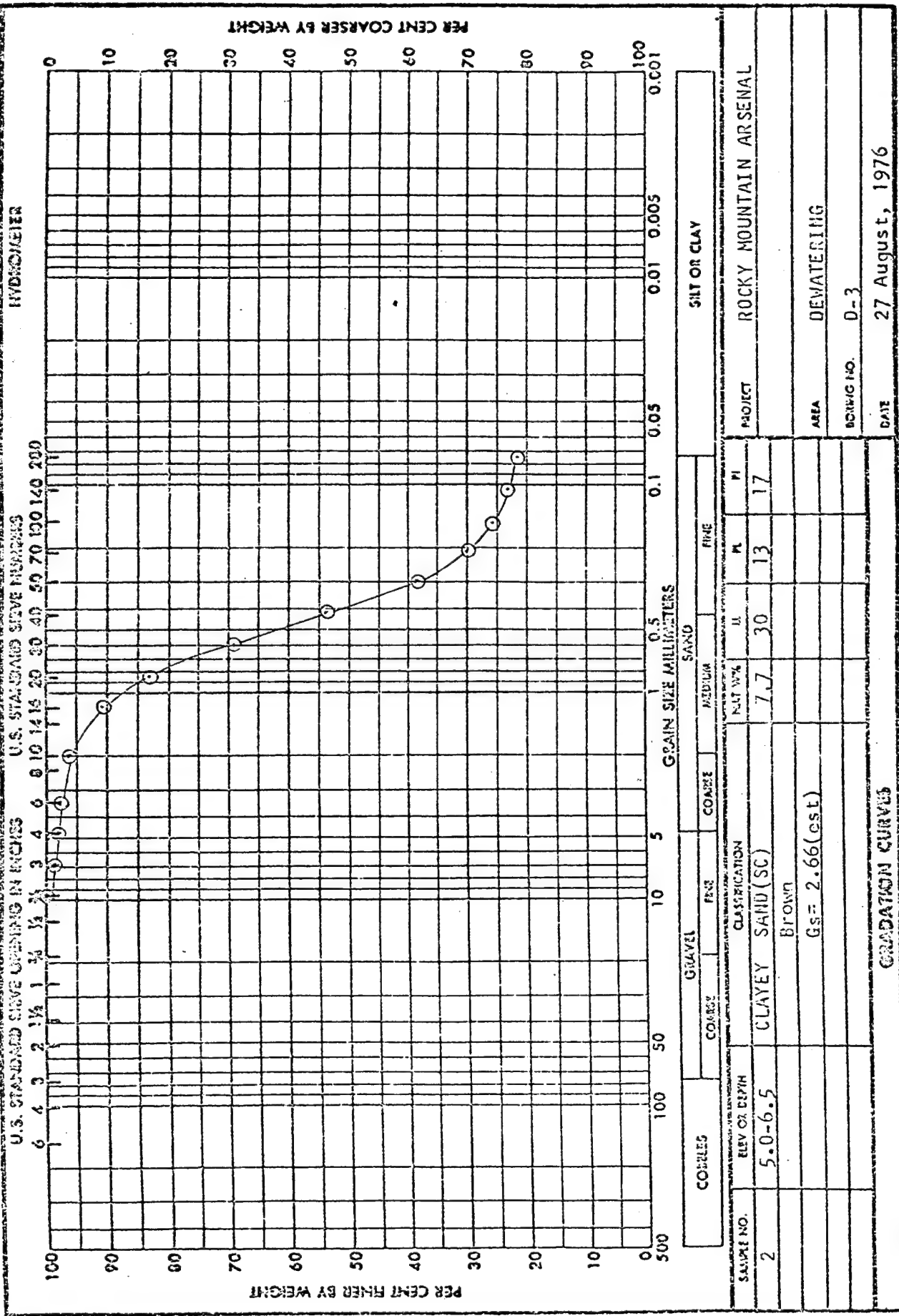
U.S. STANDARD SIEVE OPENING IN INCHES
 6 4 3 2 1 1/2 1 3/4 3/8 5/8 3/4 1 1/4 2 3 4 6 10 14 20 30 40 50 70 100 140 200



COBBLES		GRAVEL		SAND		SILT OR CLAY	
ELEV OR DEPTH		CLASSIFICATION		NAT W%		PI	
SAMPLE NO.	20.0-21.5	GRAVELLY SAND (SP-SM)		11.0		11.0	
		BROWN					
		GS = 2.66 (est)					
PROJECT				ROCKY MOUNTAIN ARSENAL			
AREA				DEWATERING			
LOGGING NO.				D-2			
DATE				27 August, 1976			

GRADATION CURVES

END FORM 2087 REFACES VES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE.
 1 MAY 63
 Ag. D₁₀ = 0.095
 -200 = 88



U.S. STANDARD SIEVE OPENINGS IN INCHES		U.S. STANDARD SIEVE NUMBERS	
6	4	3	2
10	20	40	60
100	200	400	600

COBBLES		GRAVEL		SAND		SILT OR CLAY	
COARSE	FINE	COARSE	FINE	COARSE	FINE	COARSE	FINE
CLAYEY SAND (SC)	Brown	CLAYEY SAND (SC)	Brown	CLAYEY SAND (SC)	Brown	CLAYEY SAND (SC)	Brown
GS = 2.66 (est)		GS = 2.66 (est)		GS = 2.66 (est)		GS = 2.66 (est)	

SAMPLE NO.	2	REV OR DEPTH	5.0-6.5	CLASSIFICATION	CLAYEY SAND (SC)	PROJECT	ROCKY MOUNTAIN ARSENAL
AREA	DEMATERING			BORING NO.	D-3	DATE	27 August, 1976

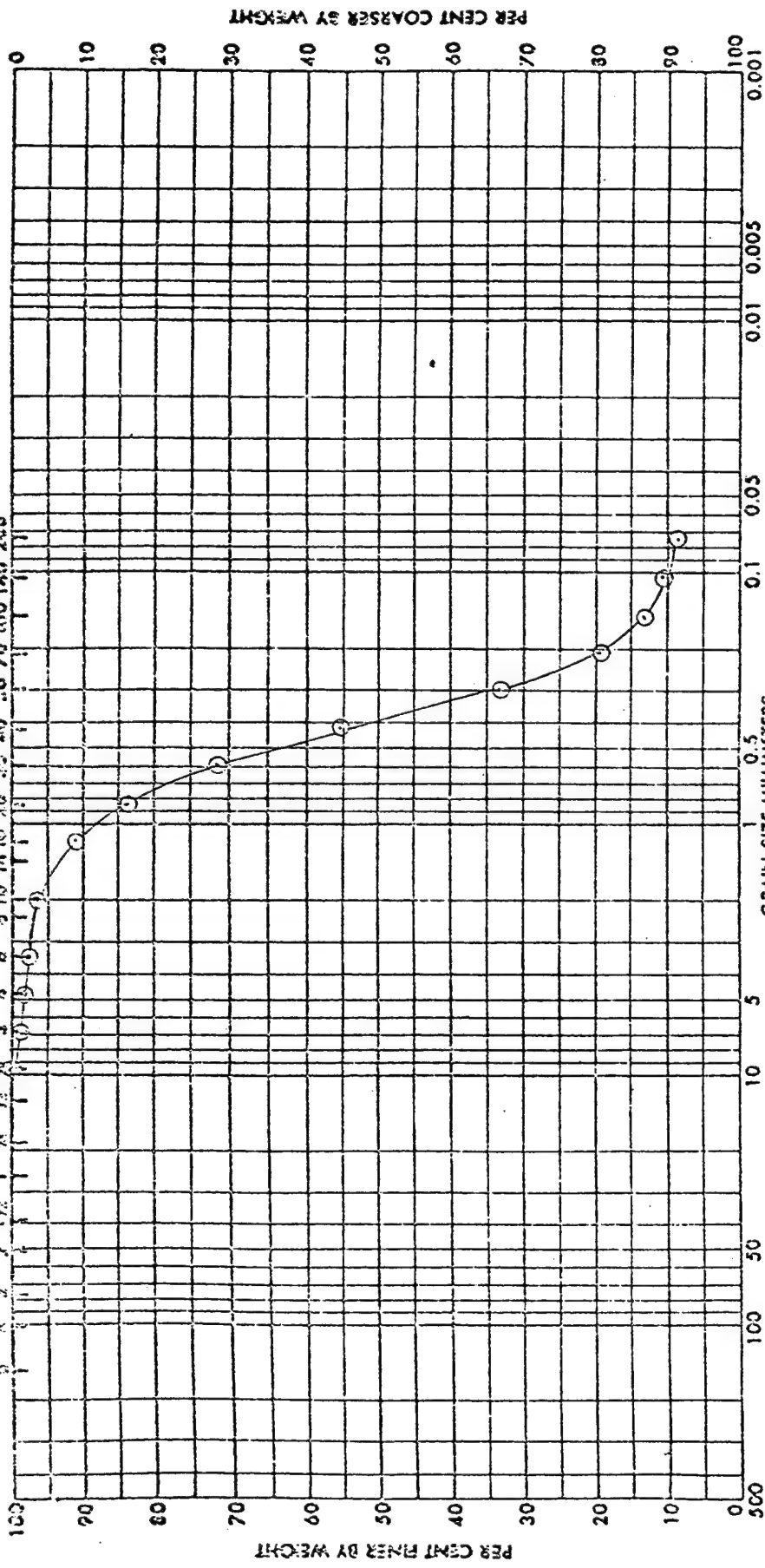
1 MAY 63

HYDROMETER

U.S. STANDARD SIEVE NUMBERS

U.S. STANDARD SIEVE OPENING IN INCHES

4 6 10 20 40 60 100 140 200



PER CENT COARSER BY WEIGHT

PER CENT FINER BY WEIGHT

CORRIES		GRAVEL		SAND		SILT OR CLAY	
ELEV OR DPTH		CLASSIFICATION		MAT W%		PROJECT	
15.0-16.5		SAND (SP-SH)		18.3		ROCKY MOUNTAIN ARSENAL	
		Brown					
		Gs = 2.66 (est)				AREA DEWATERING	
						BORING NO. 0-3	
						DATE 27 August, 1976	

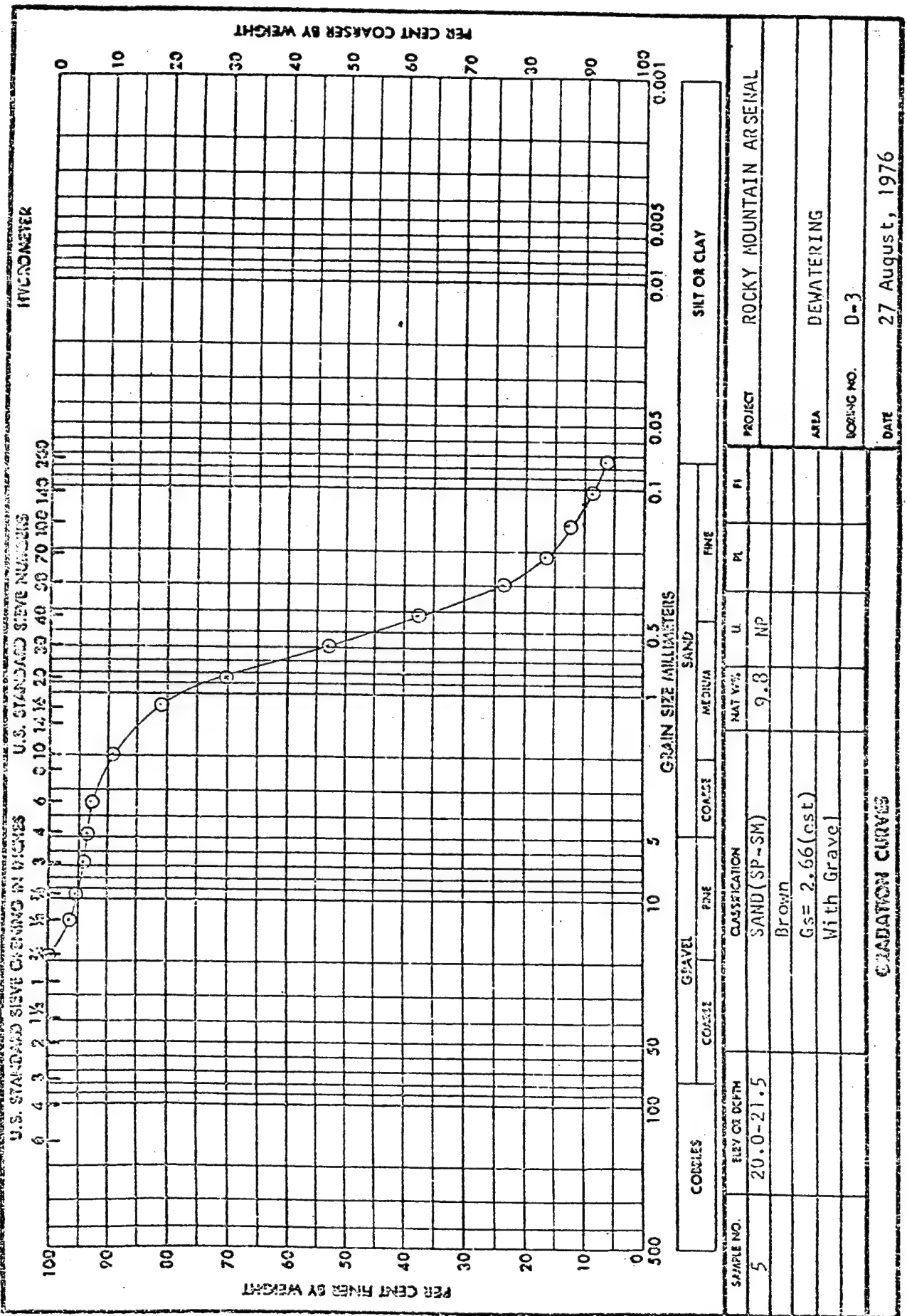
GRADATION CURVES

REPLACES WES ROCK NO. 1241, SEP 1962, WHICH IS OBSOLETE.

END FORM 2027
1 MAY 63

U.S. GOVERNMENT PRINTING OFFICE: 1961 O-779-168

Ag D₁₀ = 0.10
-200:92



U.S. GOVERNMENT PRINTING OFFICE: 1962 OF-703-118

*Ag 4% = 0.11
-200 = 7%*

REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE.

ENG FORM 2087
1 MAY 63

DATE 27 August, 1976

WORKING NO. D-3

AREA DEWATERING

PROJECT ROCKY MOUNTAIN ARSENAL

SAMPLE NO.	ELEV OR DEPTH	GRAVEL		SAND		FINE		FI
		COARSE	FINE	COARSE	MEDIA	U	PL	

5	20.0-21.5	SAND (SP-SM)		9.8	NP			
		Brown						
		Gs = 2.66 (est)						
		With Gravel						

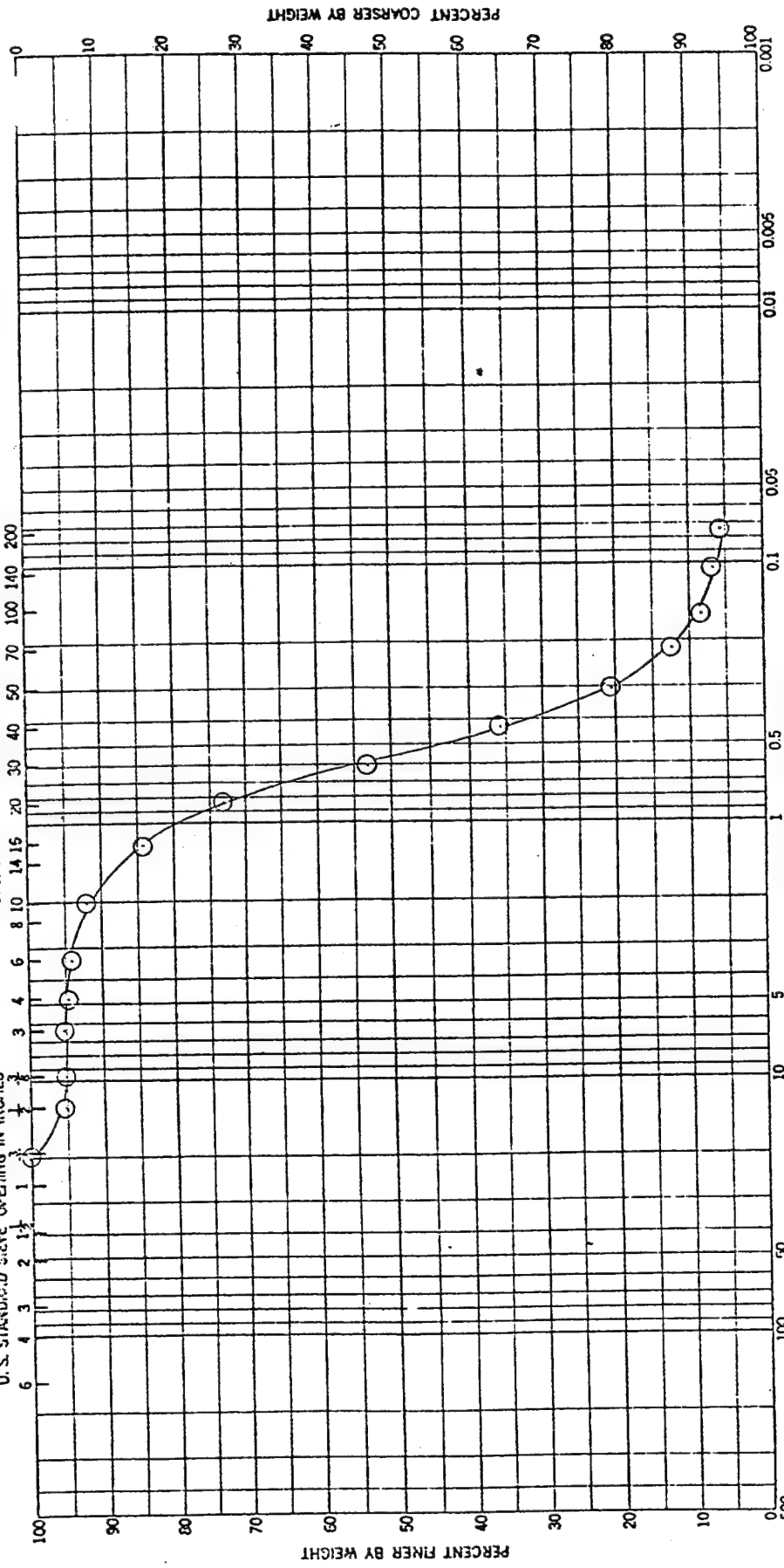
GRADATION CURVES

HYDROMETER

SIEVE NUMBERS

U.S. STA.

U.S. STANDARD SIEVE OPENING IN INCHES



SILT OR CLAY

SAND

GRAIN SIZE IN MILLIMETERS

COBBLES

GRAVEL

COARSE

FINE

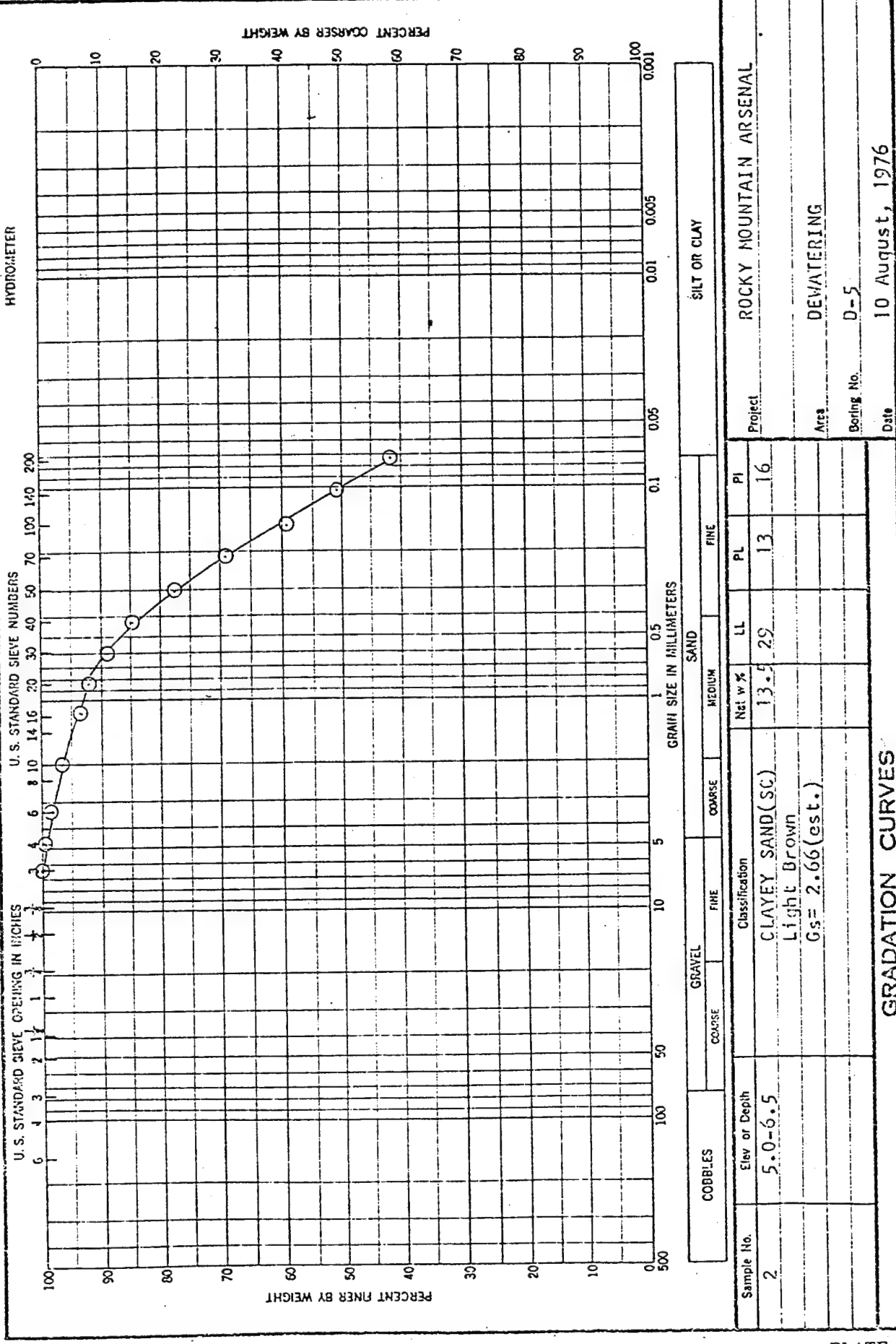
Classification

Sample No.	6-A	Elev or Depth	25.0-25.8	Classification	SAND (SP-SM) With Trace Gravel Brown Gs = 2.66 (est)	Nat w %	19.2	LL	NP	PL	PI
<p>Project: ROCKY MOUNTAIN ARSENAL</p> <p>Area: DEVATERING</p> <p>Boring No.: D-3</p> <p>Date: 3 Sept., 1976</p>											

GRADATION CURVES

Ag. $D_{10} = 0.18$
- 200 = 6%

ENG FORM 2087
1 MAY 63



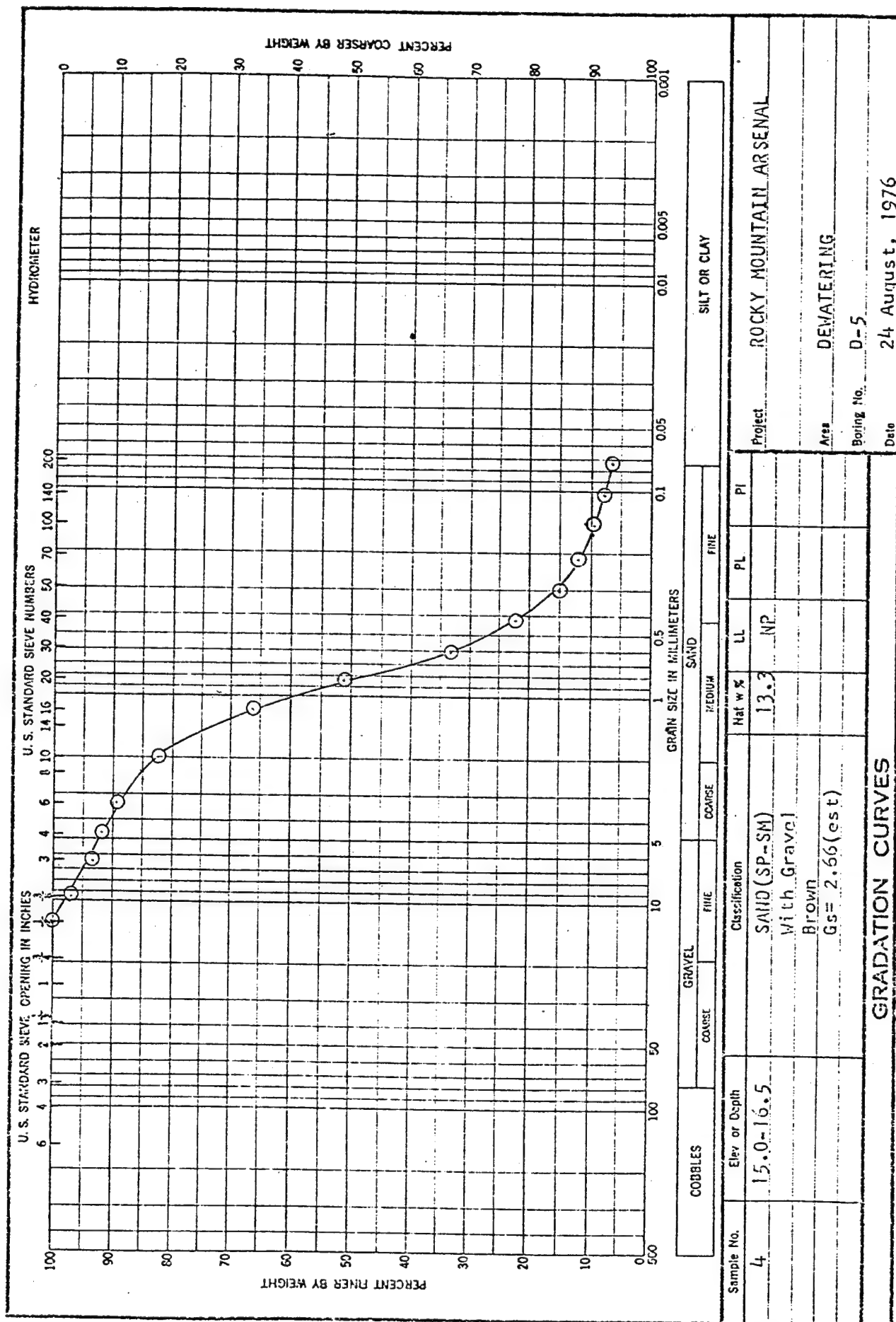
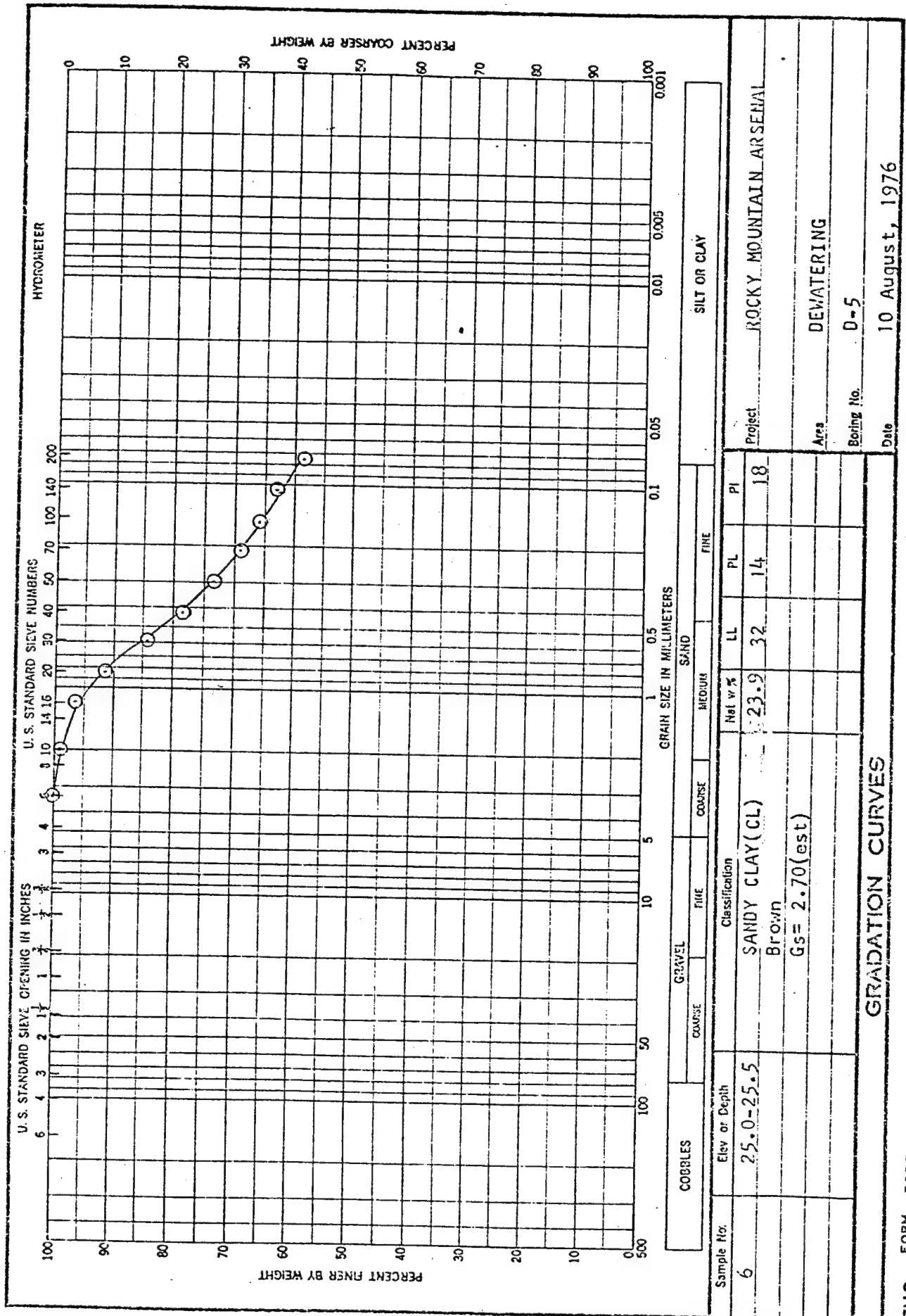
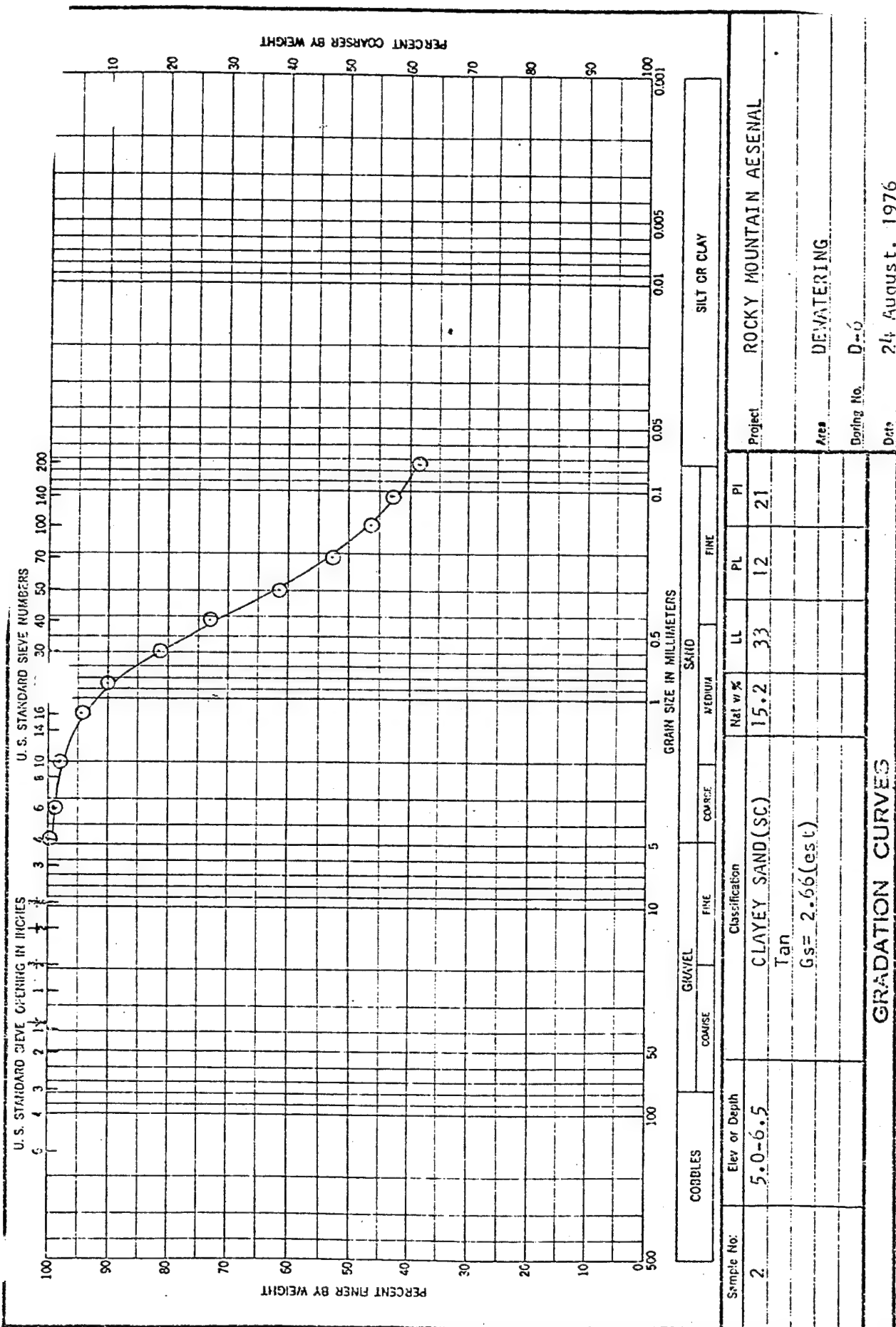


PLATE 37

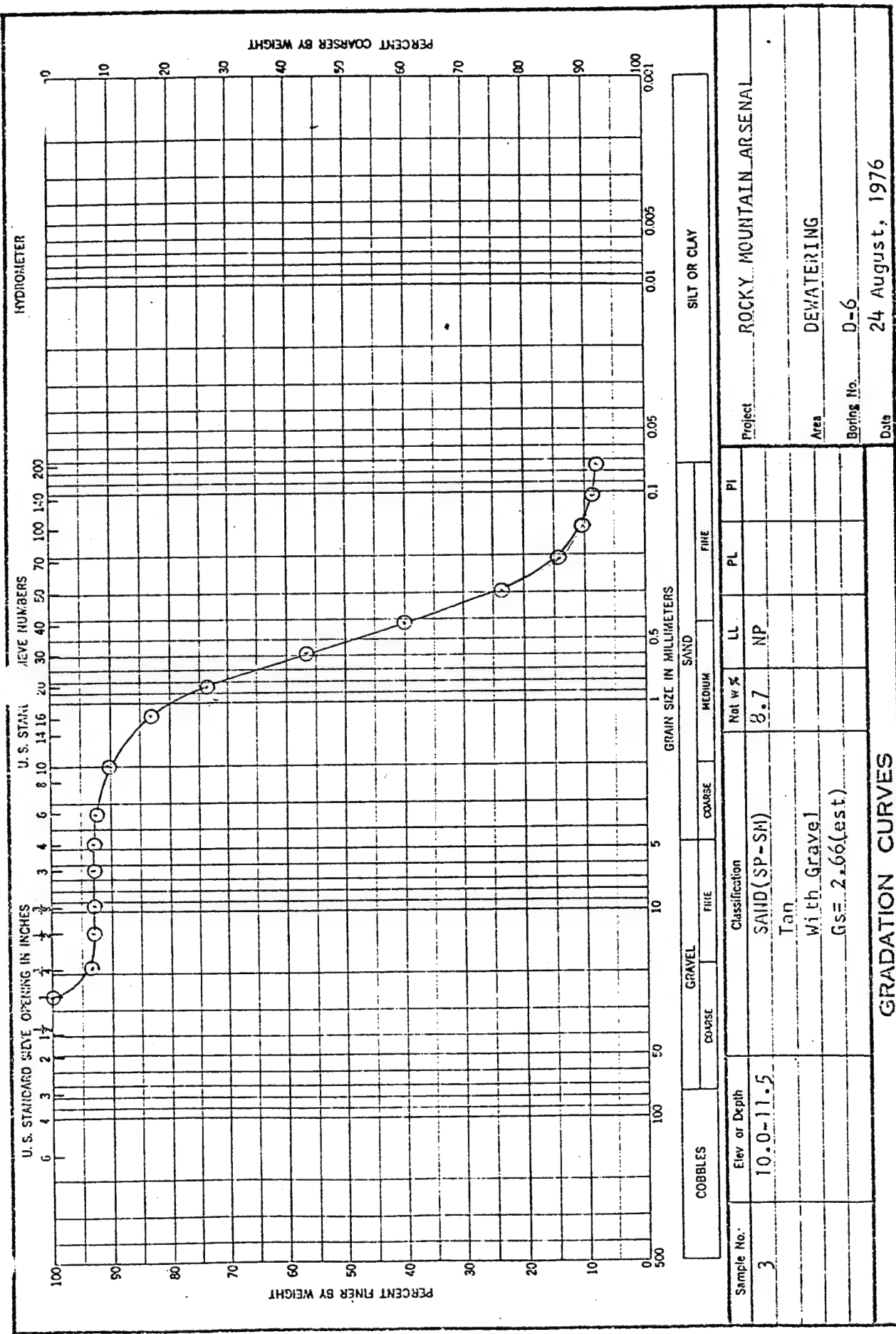
ENG FORM
1 MAY 63 2037

Ag. $D_{60} = 0.17$
-200 7%



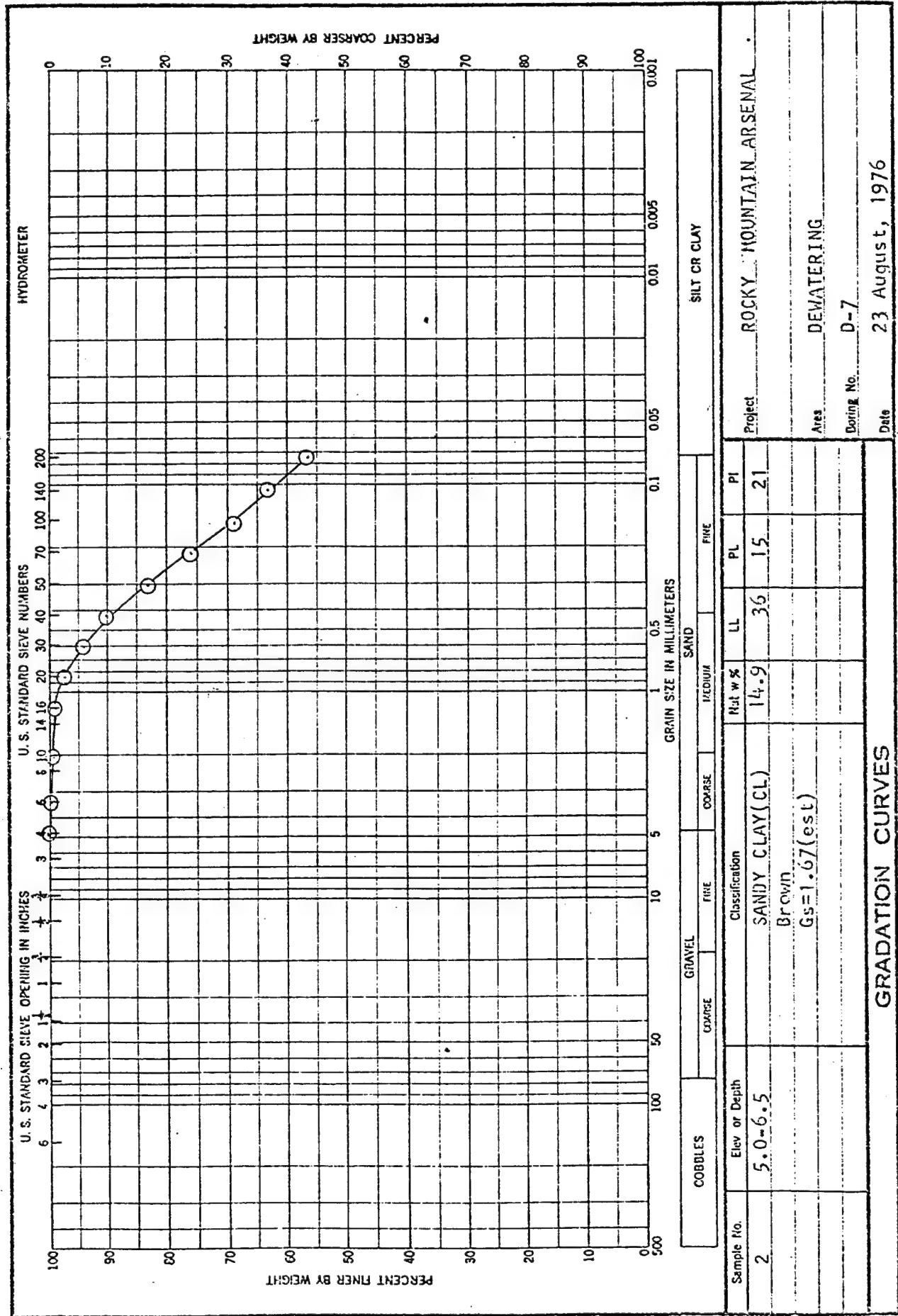


ENG FORM 2087
1 MAY 63



Ag. $D_{10} = 0.13$
 $-200 = 8\%$

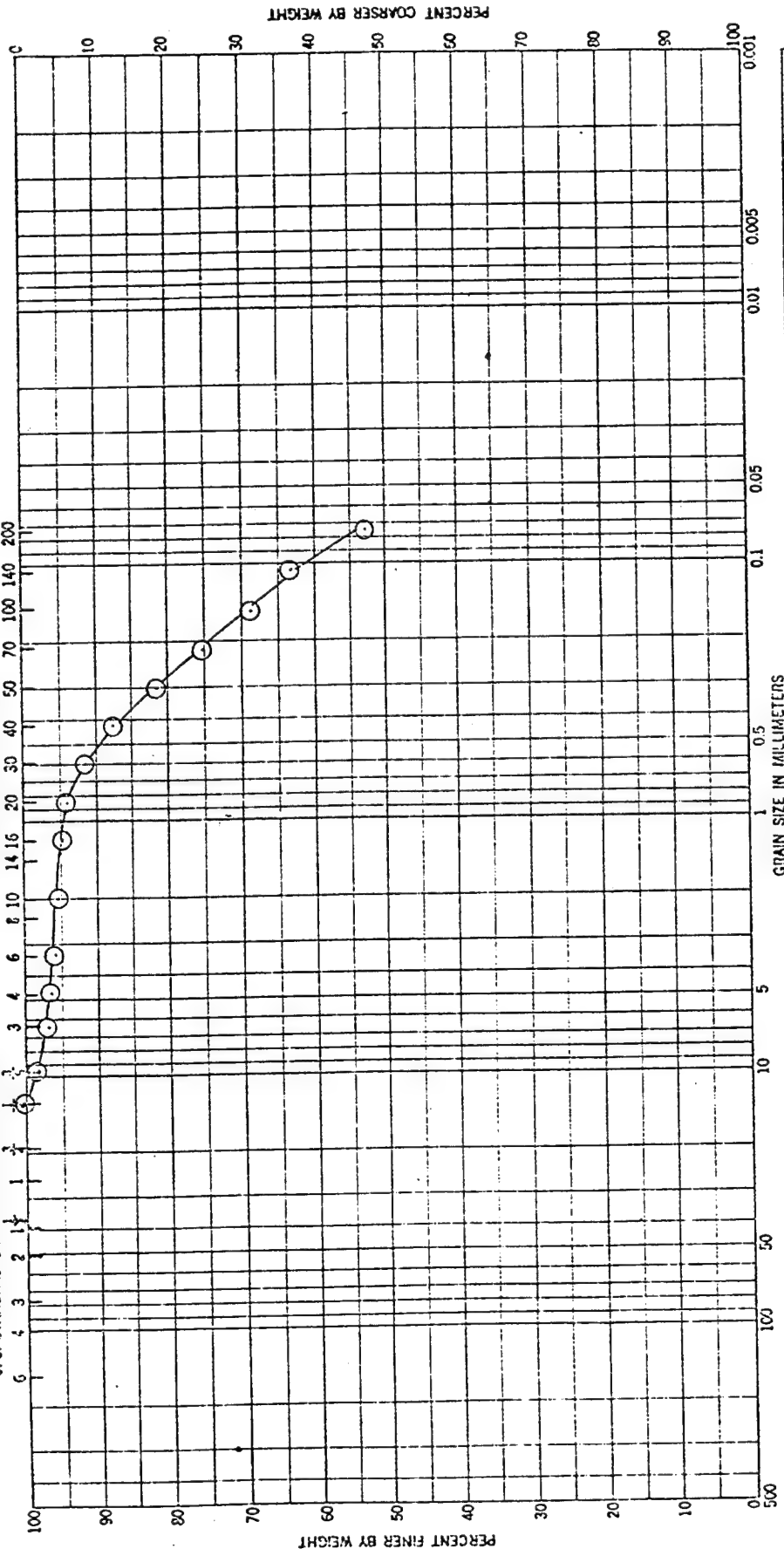
ENG FORM 1 MAY 63 2087



HYDROMETER

U. S. STANDARD SIEVE NUMBERS

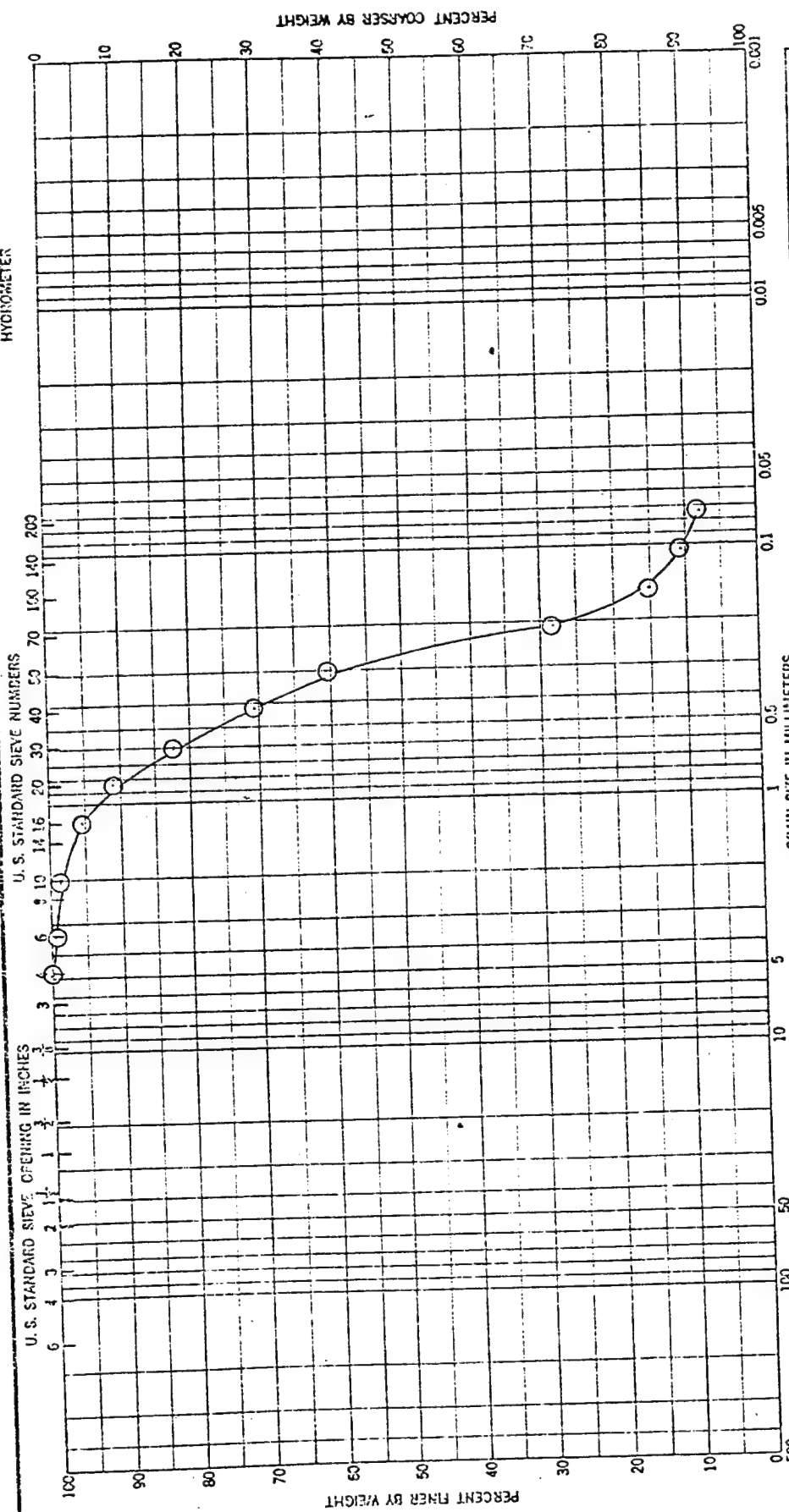
U. S. STANDARD SIEVE OPENING IN INCHES



COBBLES		GRAVEL		SAND		SILT OR CLAY	
Sample No.	Elev or Depth	Classification	Net wt %	LL	PL	PI	Project
3	10.0-11.5	SANDY CLAY (CL) With trace Gravel Light Brown Gs=2.67(est)	22.7	26	14	12	ROCKY MOUNTAIN ARSENAL
							Area DEWATERING
							Doping No. D-7
							Date 23 August, 1976

GRADATION CURVES

HYDROMETER



COBBLES		GRAVEL		SAND		FINE		SILT OR CLAY	
Elev or Depth		Classification		Flat w %		LL		PI	
15.0-16.5		SAND (SP-SM) Light Brown Gs = 2.65 (est)		20.3		NP			
Sample No.		4							
Project		ROCKY MOUNTAIN ARSENAL							
Area		DEWATERING							
Boring No.		D-7							
Date		23 August, 1976							

GRADATION CURVES

Ag. $D_{10} = 0.095$
 $-200 = 8\%$

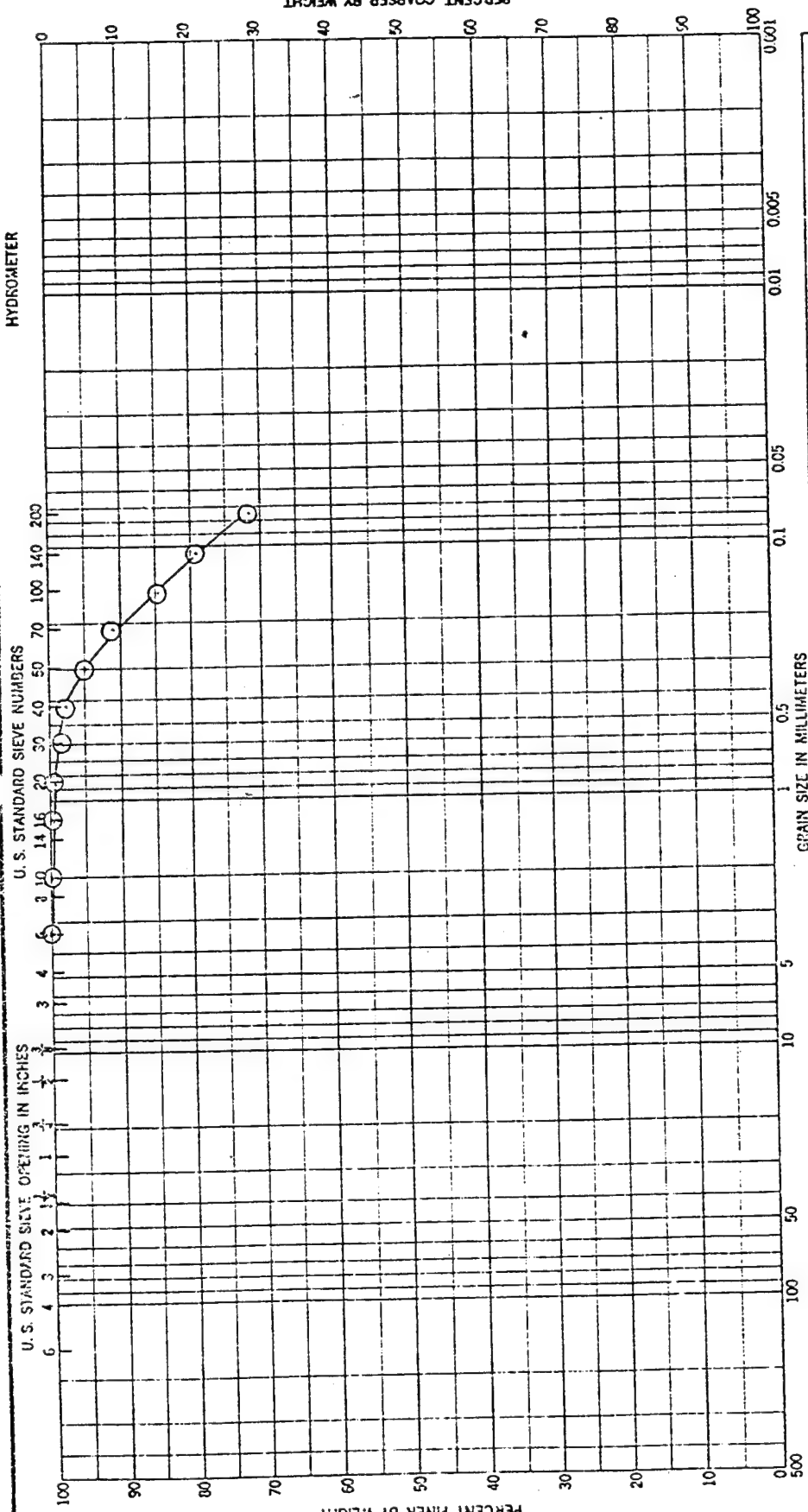
HYDROMETER

U. S. STANDARD SIEVE NUMBERS

U. S. STANDARD SIEVE OPENING IN INCHES

PERCENT COARSER BY WEIGHT

PERCENT FINER BY WEIGHT



GRAIN SIZE IN MILLIMETERS

SILT OR CLAY

SAND

FINE

MEDIUM

COARSE

FINE

COARSE

FINE

COARSE

FINE

COARSE

FINE

Project ROCKY MOUNTAIN ARSENAL

PI

PL

LL

Ht w %

Classification

CLAYEY, SANDY SILT(HH)

Brown

Gs= 2.70(est)

Elev or Depth

25.0-26.5

Sample No.

6

Area DEWATERING

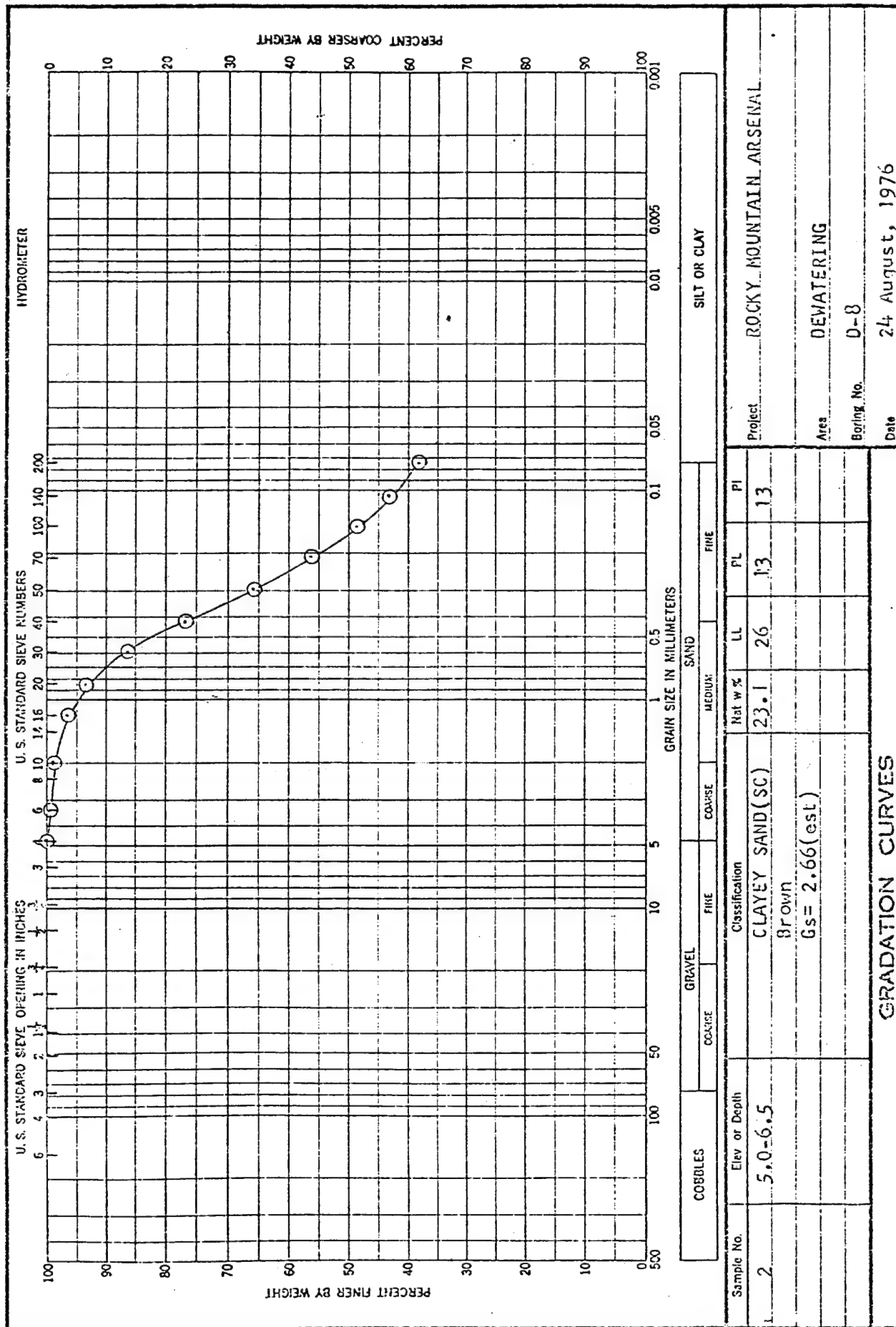
Boring No. 0-7

Date 23 August, 1976

GRADATION CURVES

ENG FORM 2087
1 MAY 63

PLATE 48



U.S. STANDARD SIEVE NUMBERS

U.S. STANDARD SIEVE OPENING IN INCHES

HYDROMETER

PERCENT COARSER BY WEIGHT

PERCENT FINER BY WEIGHT

GRAIN SIZE IN MILLIMETERS

SILT OR CLAY

SAND

GRAVEL

COBBLES

COARSE

FINE

Classification

Sample No.

Elev or Depth

10.0-11.5

SAND (SP-SM)

tan

Gs = 2.66 (est)

21.3

NP

PL

PI

Project

Area

Boring No.

Date

Rocky Mountain Arsenal

DeWATERING

D-3

24 August, 1976

GRADATION CURVES

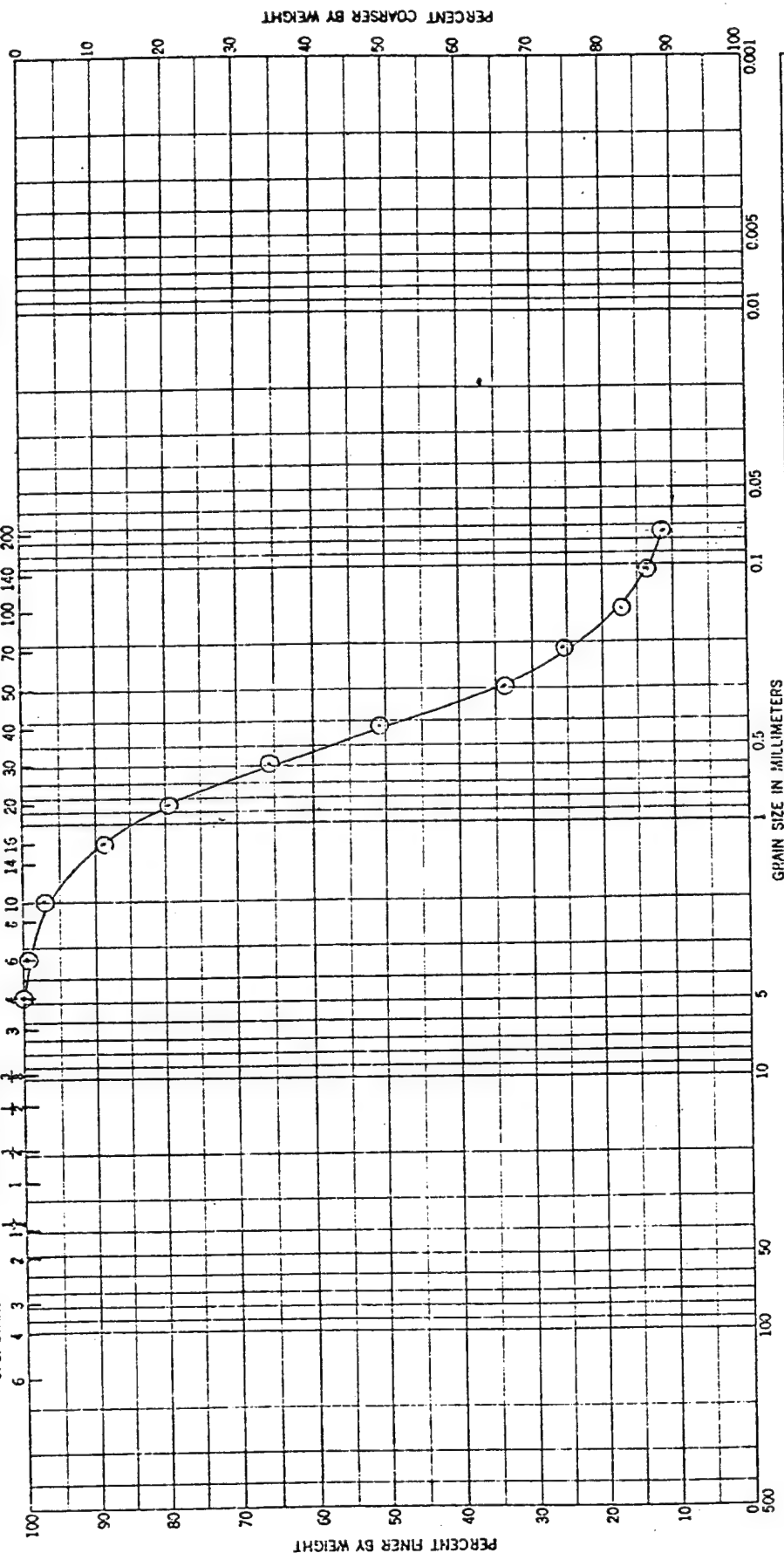
ENG FORM 1 MAY 63 2037

Ag. $D_{10} = 0.14$
- 200 = 7%

HYDROMETER

U.S. STANDARD SIEVE NUMBERS

U.S. STANDARD SIEVE OPENING IN INCHES



SILT OR CLAY

GRAIN SIZE IN MILLIMETERS

COARSE

FINE

COARSE

FINE

COBBLES

Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
4	15.0-16.5	SAND (SP-SM) Brown Gs = 2.66 (est)	16.8	NP		
Project ROCKY MOUNTAIN ARSENAL						
Area DEVATERING						
Bedding No. D-8						
Date 24 August, 1976						

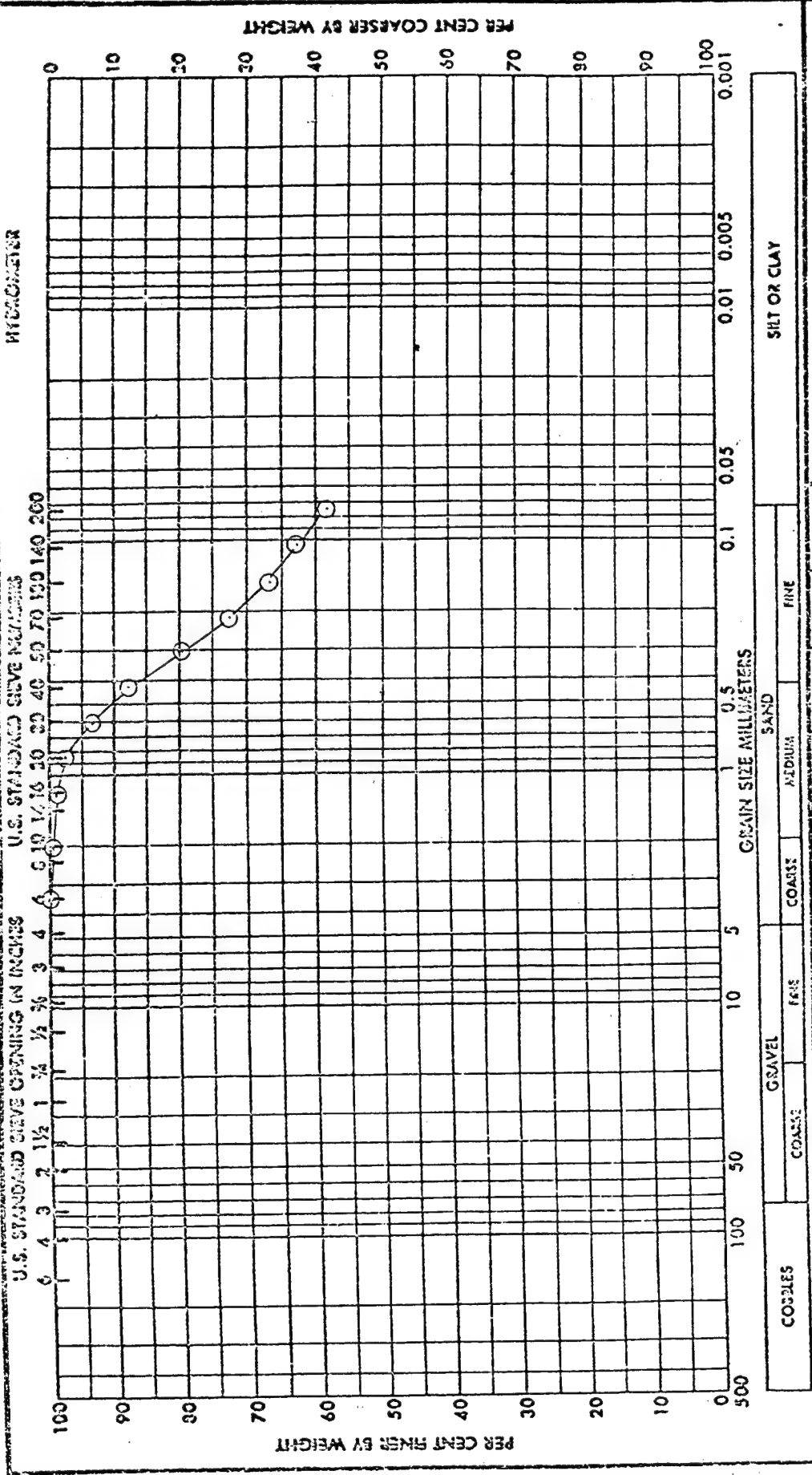
GRADATION CURVES

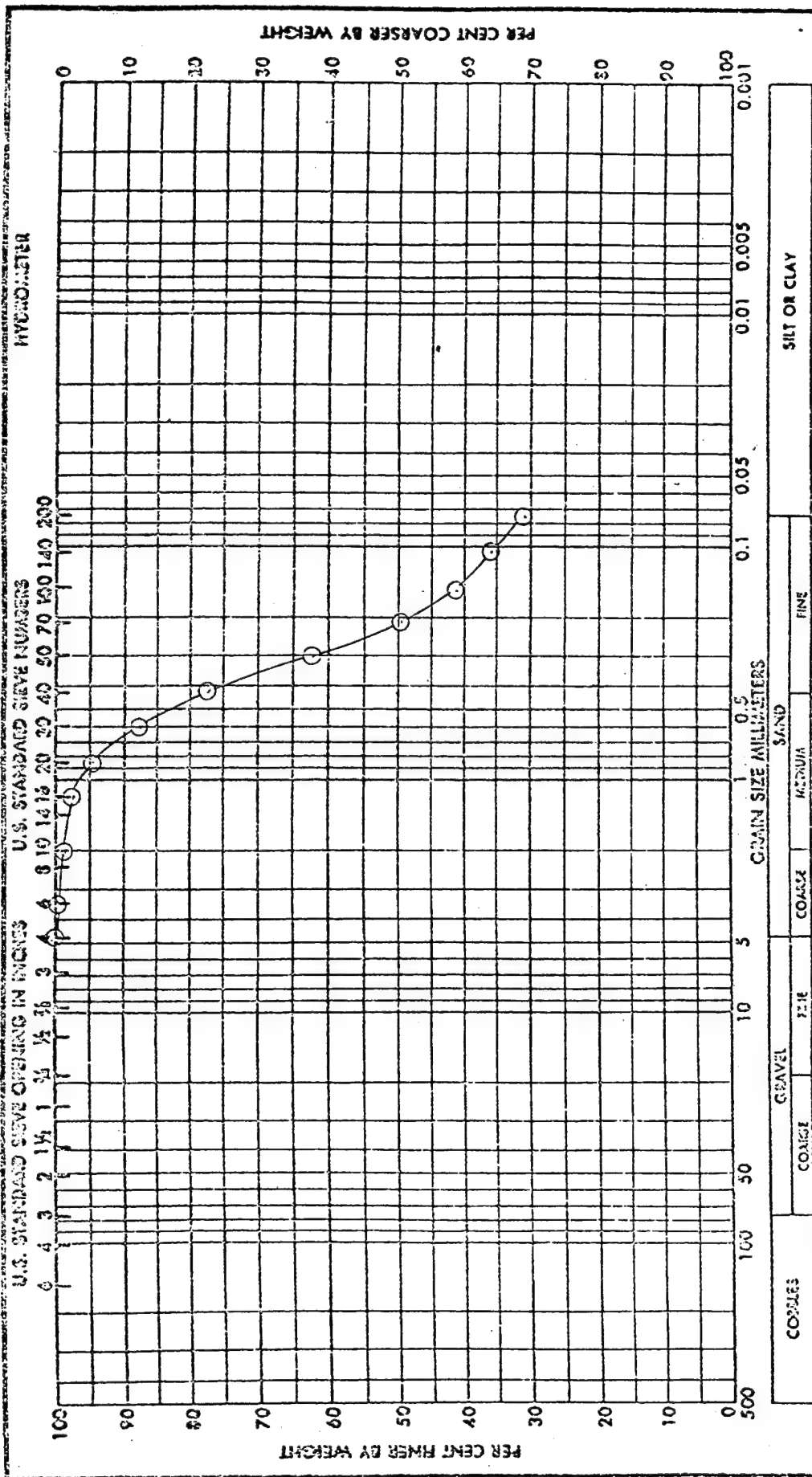
Ag D_{10} : last than -200

-200 = 12%

ENG FORM 2087
1 MAY 63

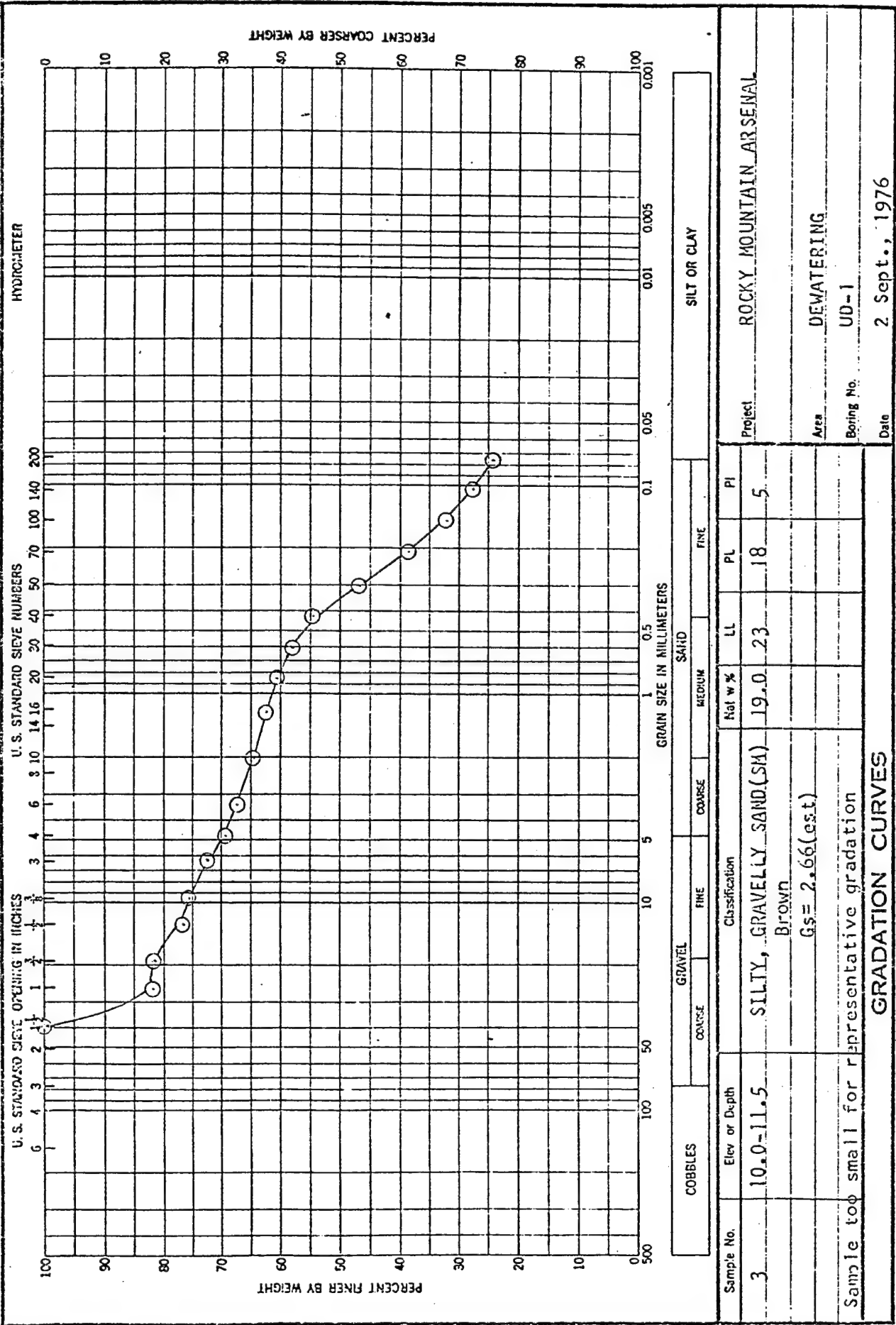
PLATE 51

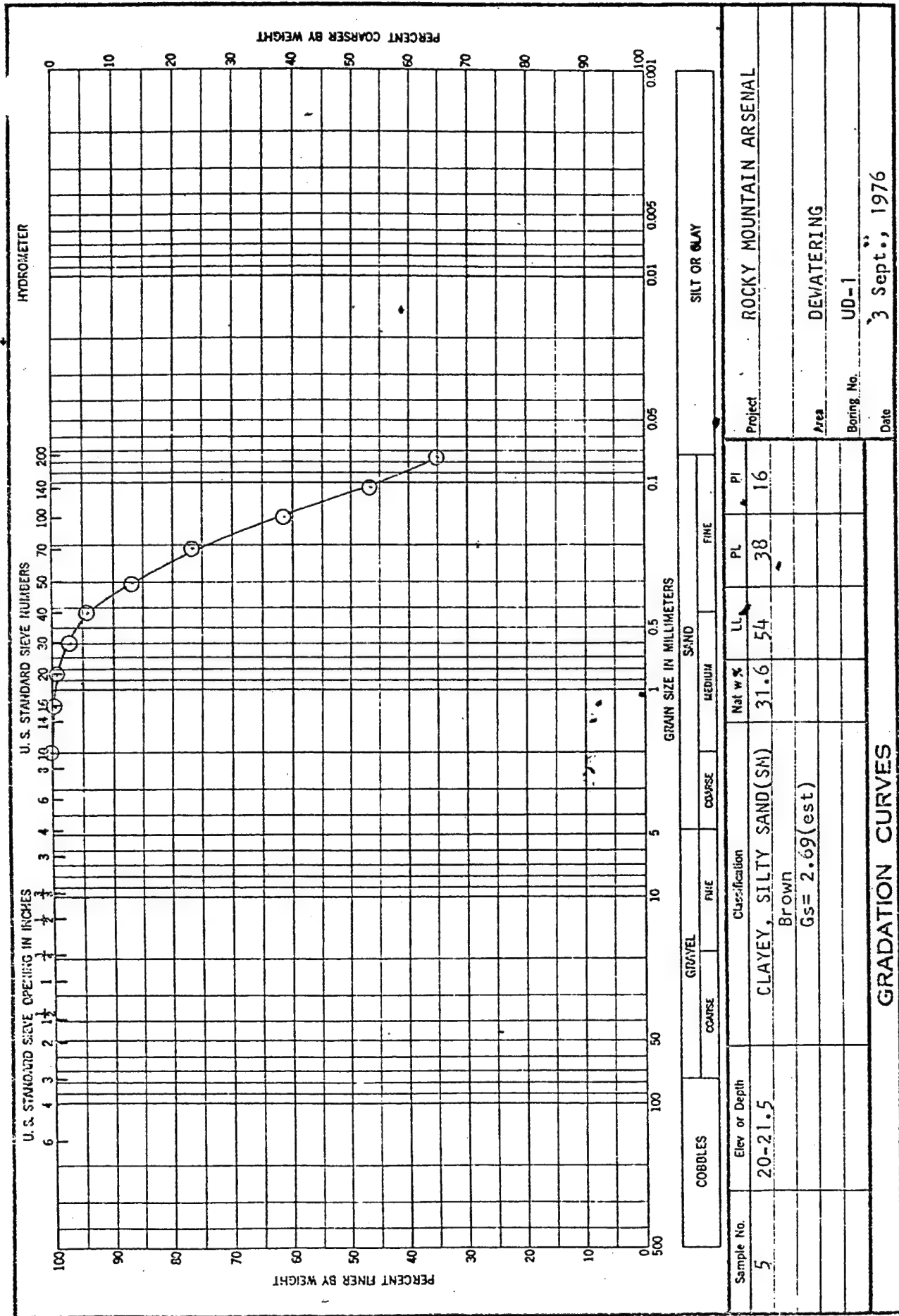




U.S. STANDARD SIEVE OPENING IN INCHES		U.S. STANDARD SIEVE NUMBERS	
0	4	4	4
1	10	10	10
2	20	20	20
3	30	30	30
4	40	40	40
5	50	50	50
6	60	60	60
7	70	70	70
8	80	80	80
9	90	90	90
10	100	100	100

COARSE		GRAVEL		SAND		SILT OR CLAY	
COARSE	GRAVEL	COARSE	FINE	MEDIUM	FINE		
SAMPLE NO.	ELEV OR DPTH	CLASSIFICATION	NAT W%	U	FL	M	
2	5.0-6.5	SILTY SAND (SM)	14.6	22	16	6	
From Density		Grayish Brown					
		Gs=2.65(est)					
GRADATION CURVES							
PROJECT							ROCKY MOUNTAIN ARSENAL
AREA							DEWATERING
BORING NO.							UD-1
DATE							3 Sept., 1976

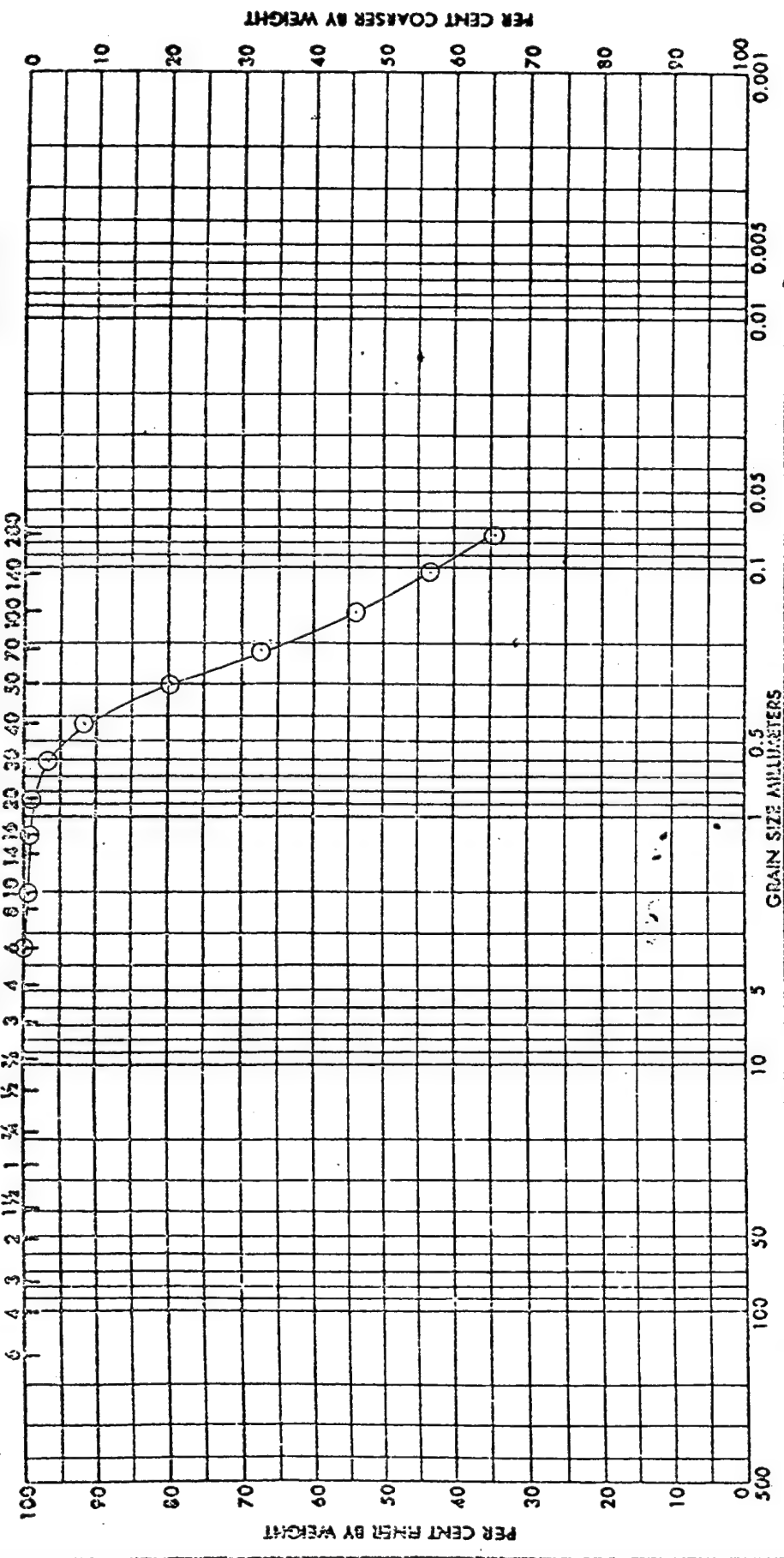




HYDROMETER

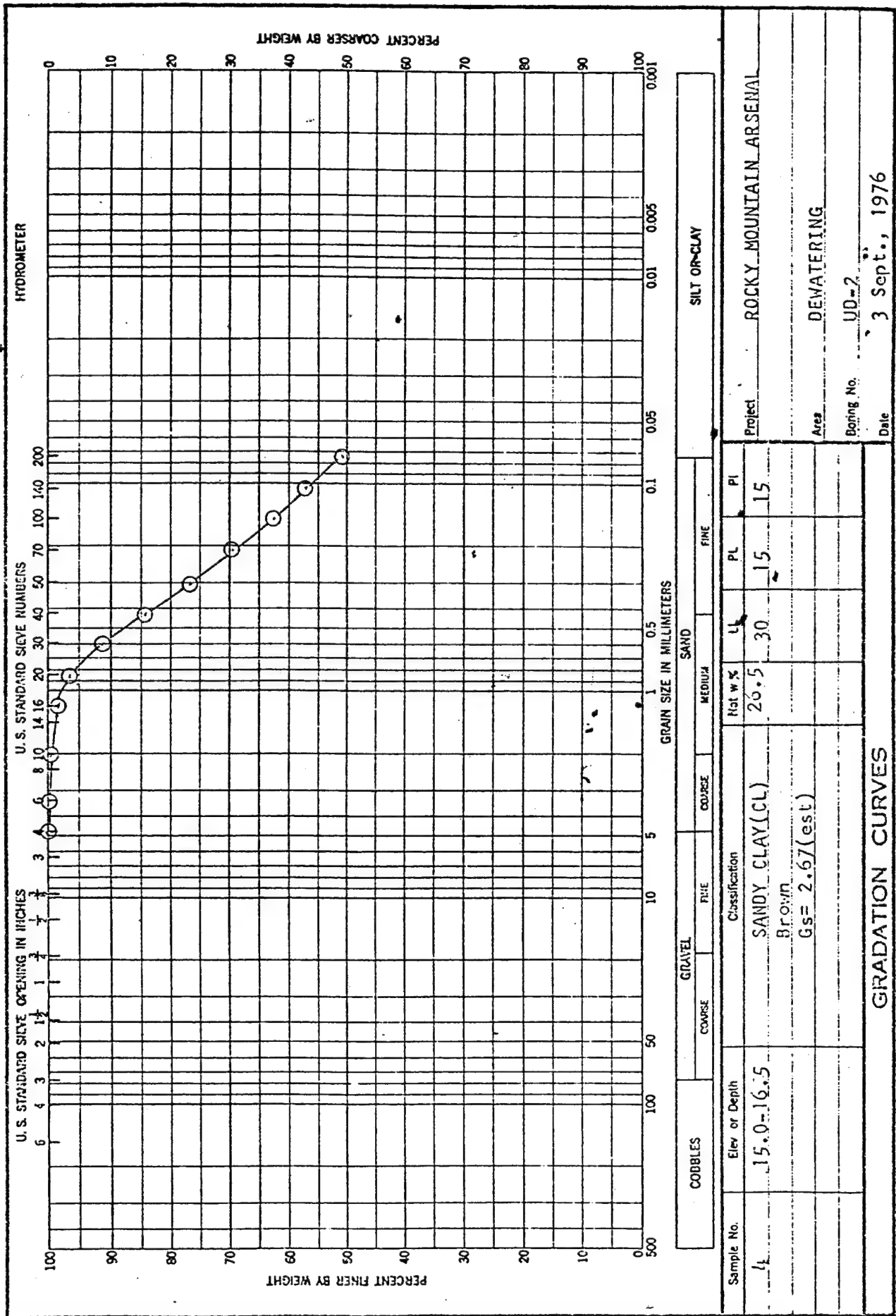
U.S. STANDARD SIEVE NUMBERS

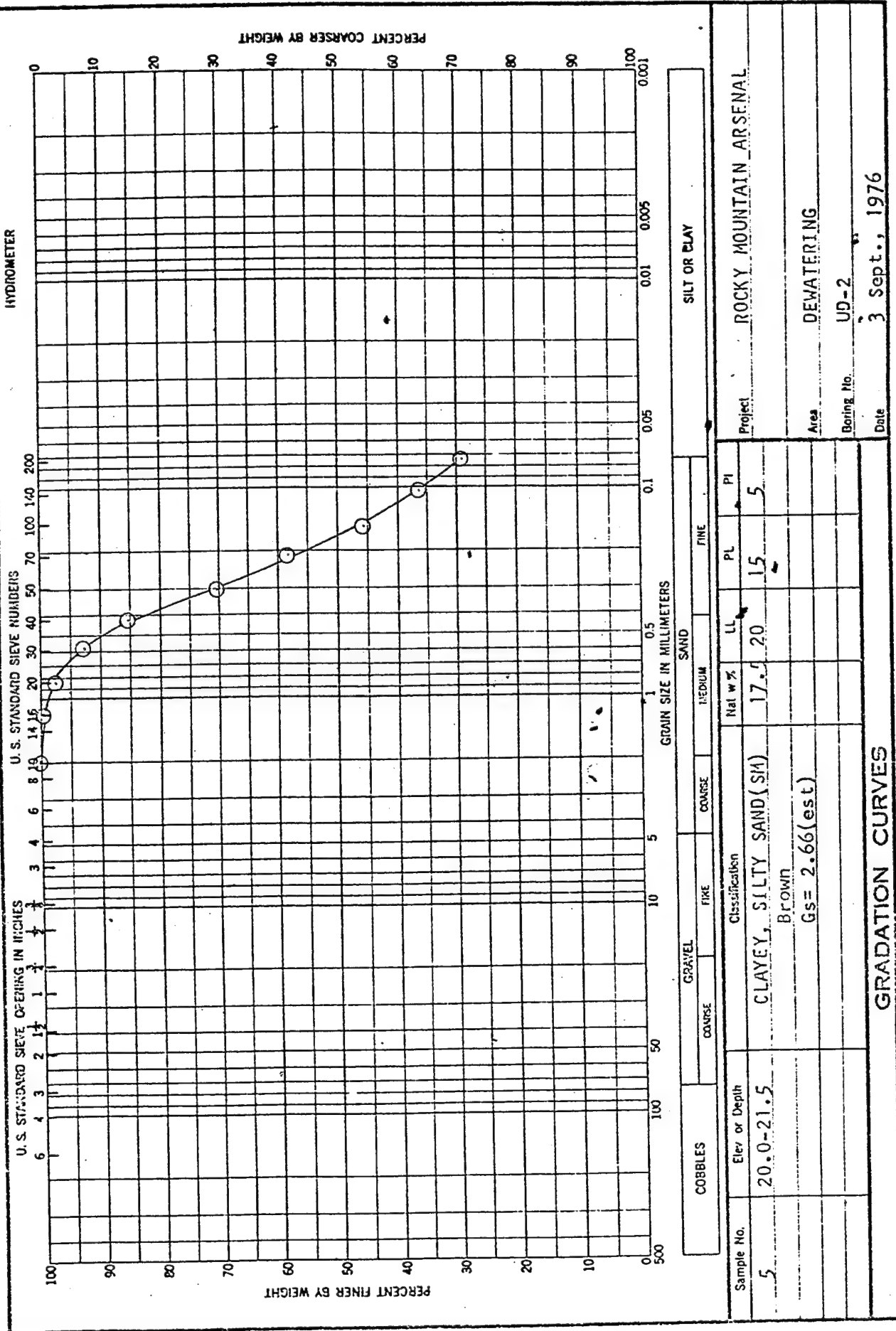
U.S. STANDARD SIEVE OPENING IN INCHES



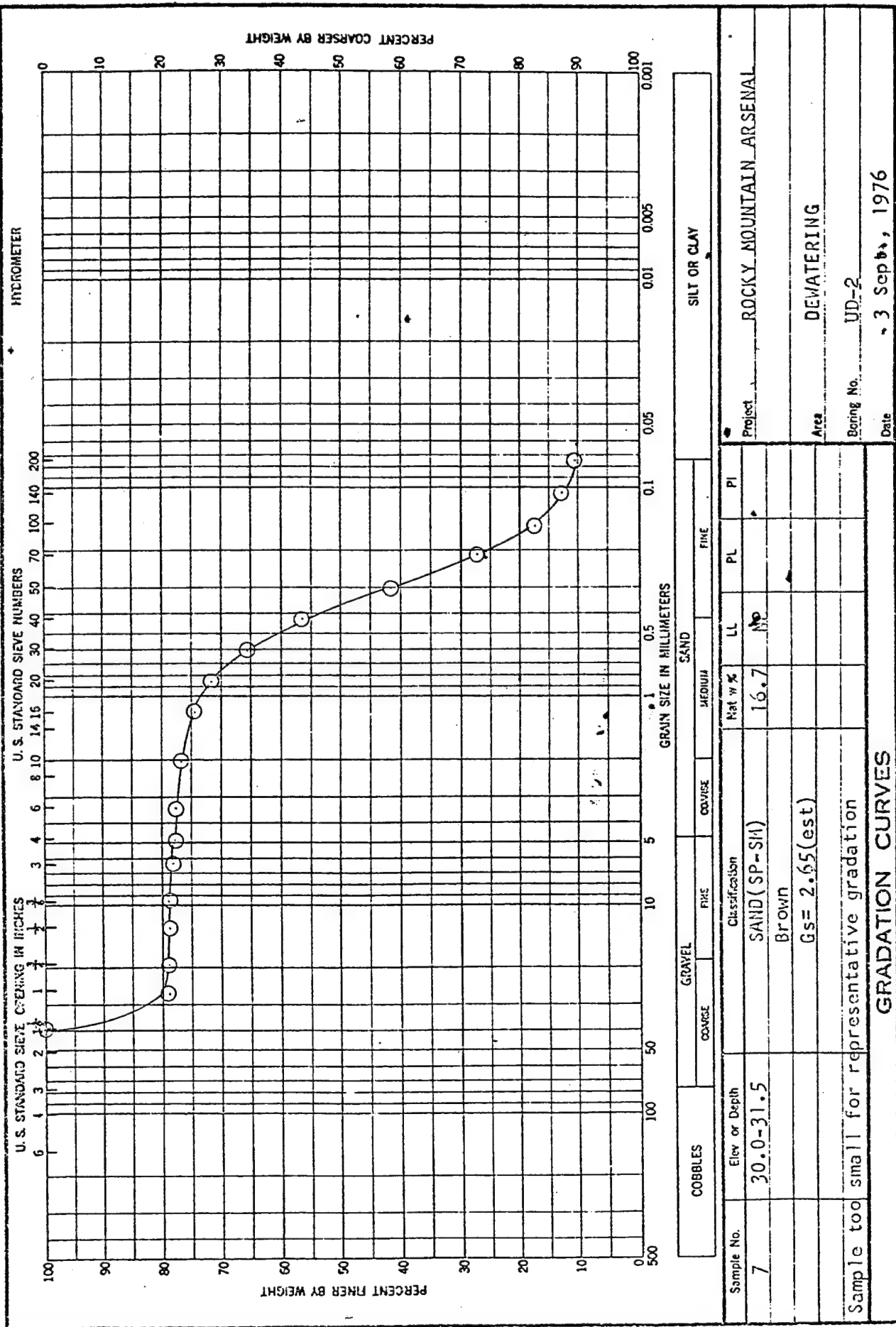
COBBLES		GRAVEL		SAND		FINE		SILT OR CLAY	
COARSE		FINE		COARSE		FINE			
SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION		NAT W%	U	FL	PI	PROJECT	
1		SILTY SAND (SM)			NP			ROCKY MOUNTAIN ARSENAL	
		Brown							
		Gs = 2.70						AREA	
								BORING NO. JD-2	
								DATE 23 Sept., 1976	

CLASSIFICATION CURVES





ENG FORM 2087
1 MAY 63

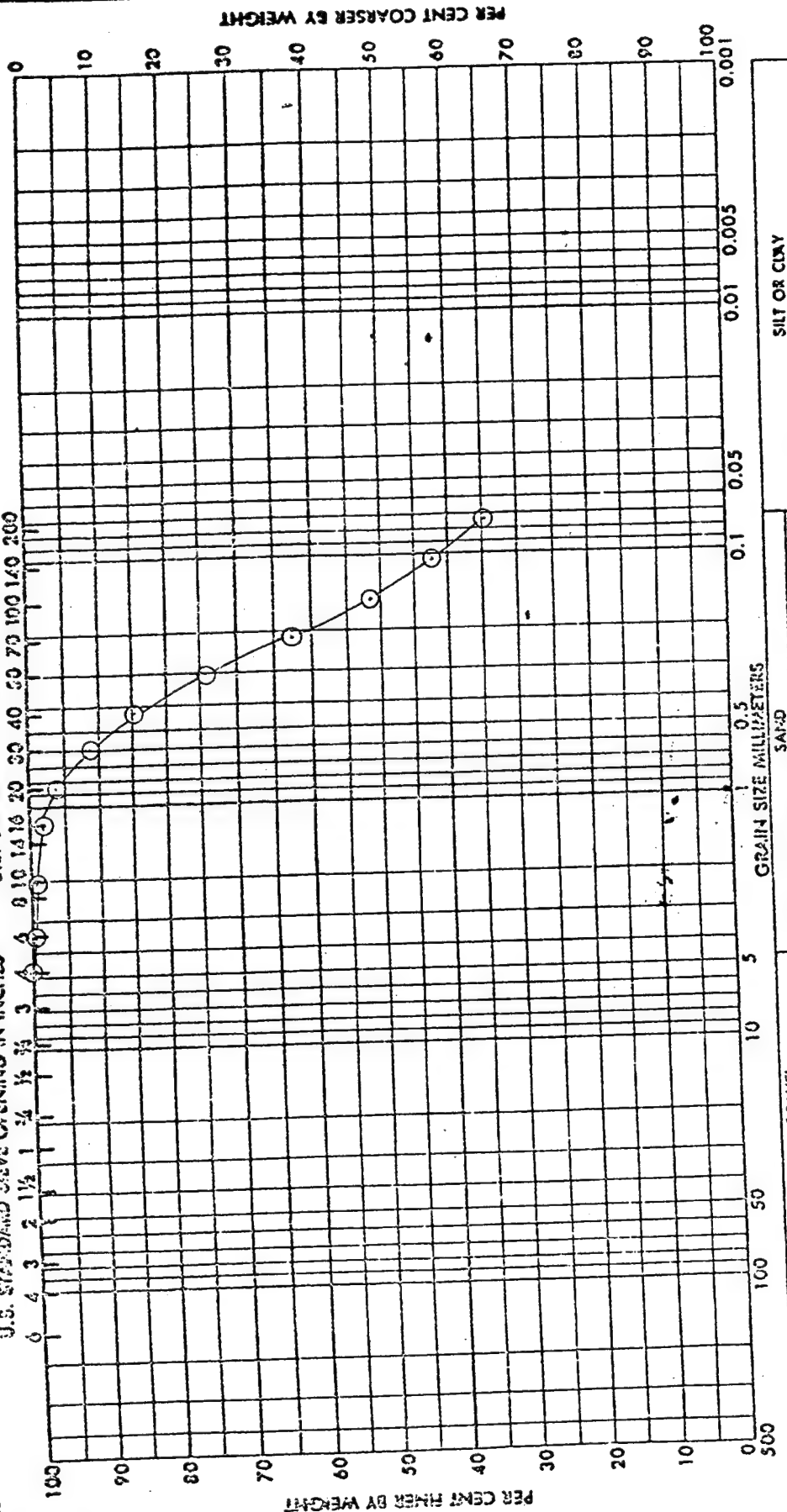


Ag. $P_{10} = \text{less than } 0.075\phi$
 $-200\phi = 11\%$

HYDROMETER

U.S. STANDARD SIEVE OPENING IN INCHES
 0 1/8 1/4 3/8 1/2 5/8 3/4 1 1 1/4 1 1/2 2 2 1/2 3 4

U.S. STANDARD SIEVE NUMBERS
 20 30 40 50 60 70 80 100 140 200



SILT OR CLAY

GRAIN SIZE MILLIMETERS

SAND

MEDIUM

COARSE

FINE

GRAVEL

COARSE

FINE

COBBLES

PROJECT ROCKY MOUNTAIN ARSENAL

AREA

DATE

FORING NO.

UD-3

23 Sept., 1976

U.S. GOVERNMENT PRINTING OFFICE: 1963 OF - 780-115

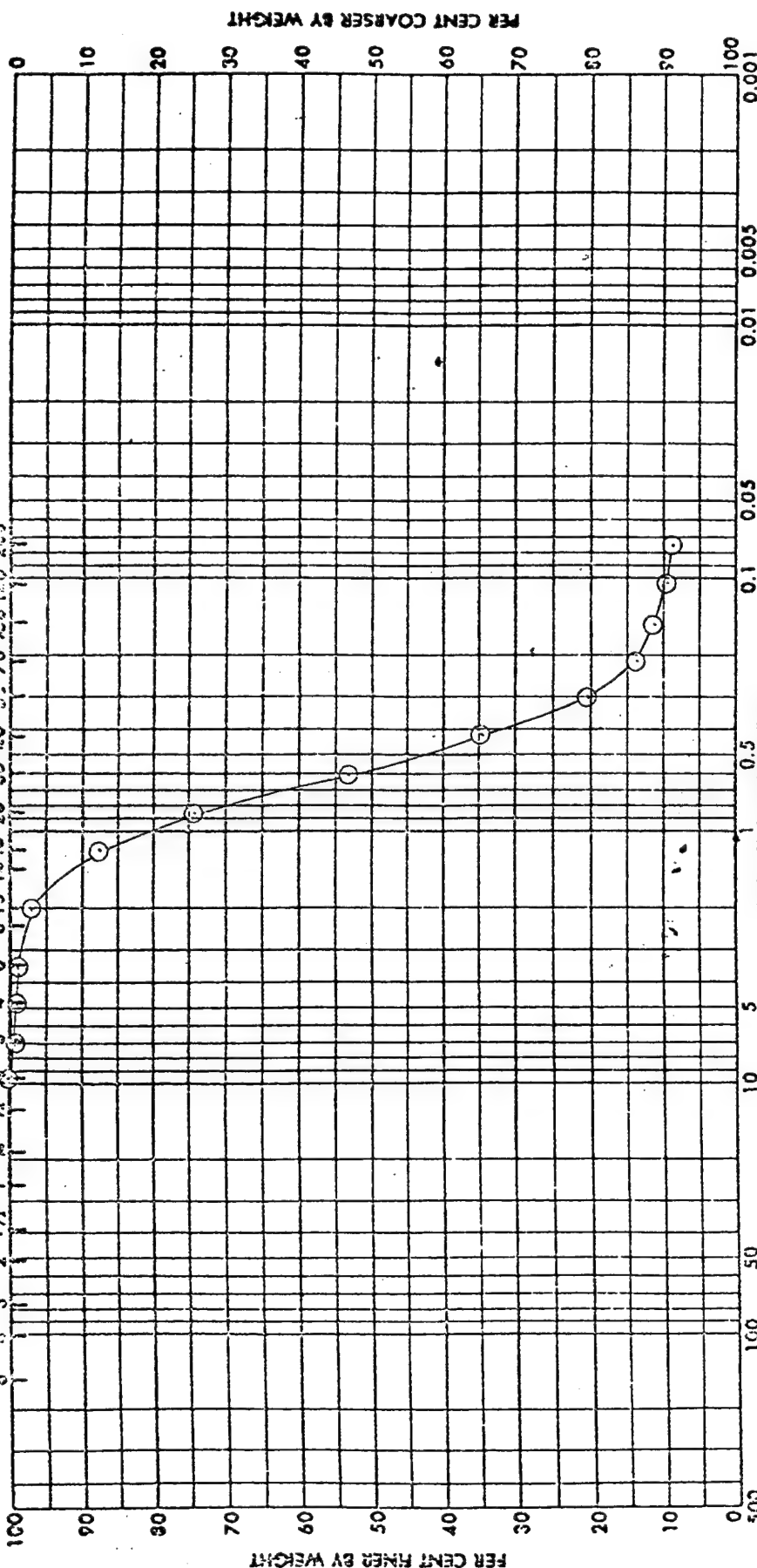
GRADATION CURVES

REPLACES WTS FOJA NO. 1241, SEP 1962, WHICH IS OBSOLETE.

END FORM 2087
 1 MAY 63

HYDROMETER

U.S. STANDARD SIEVE OPENING IN INCHES
6 4 3 2 1 1/2 1 3/4 2 3/4 3 4 6 10 14 16 20 30 40 50 70 100 140 200



COBBLES		GRAVEL		SAND		SILT OR CLAY	
COARSE		FINE		MEDIUM		FINE	
SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	U	PL	PI	
3	10.0-11.5	SAND (SP-SM) Brown Gs = 2.66 (est)	15.8	NP			
CORRECTION CURVES							
PROJECT - ROCKY MOUNTAIN ARSENAL							
AREA - DEWATERING							
BORING NO. UD-3							
DATE 3 Sept., 1976							

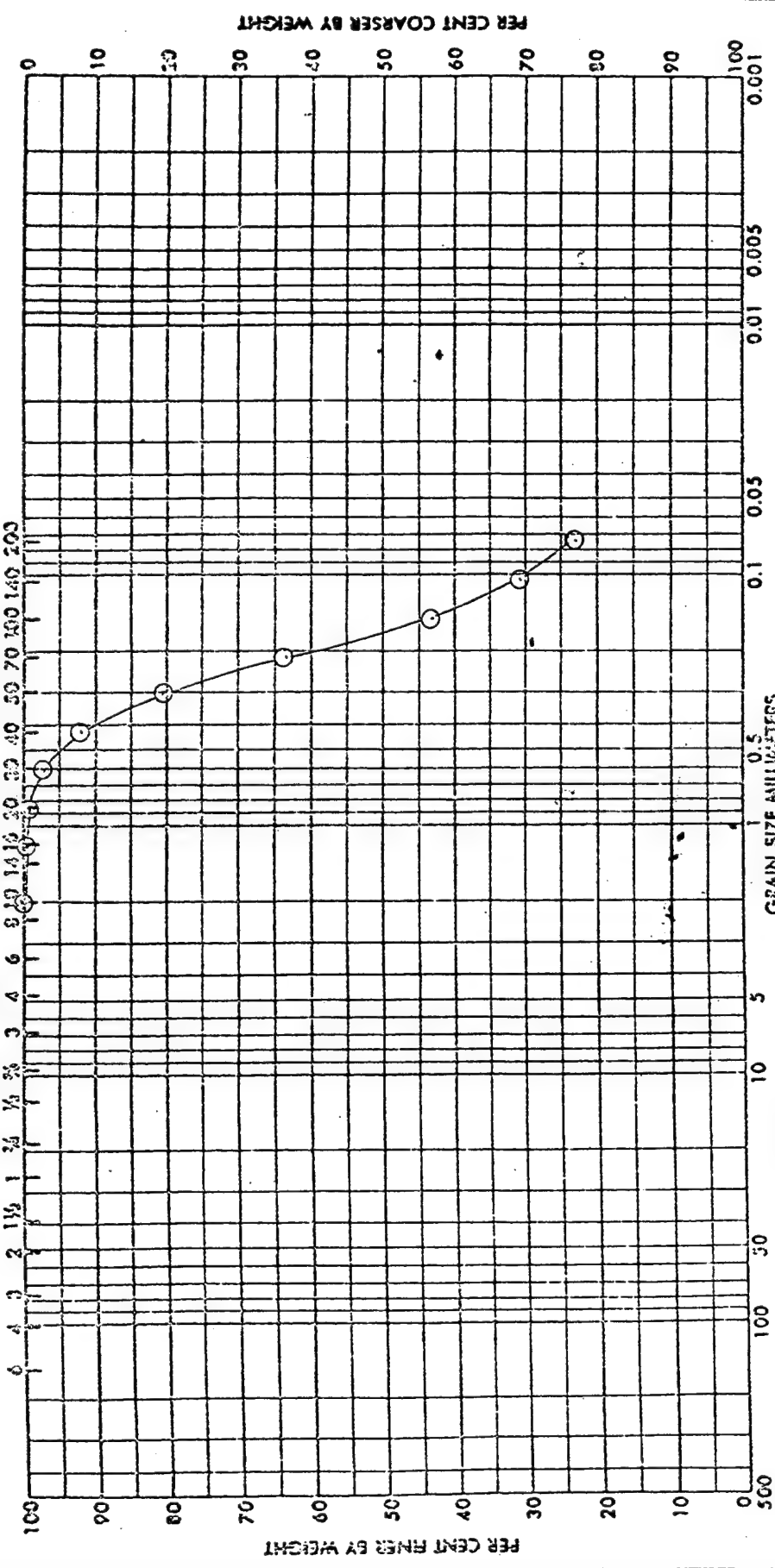
U.S. GOVERNMENT PRINTING OFFICE: 1963 OF-740-118
 Ag. $D_{10} = 0.10$
 $-200 = 9\%$

2087 REPLACES WES FORM NO. 1261, SEP 1962, WHICH IS OBSOLETE.

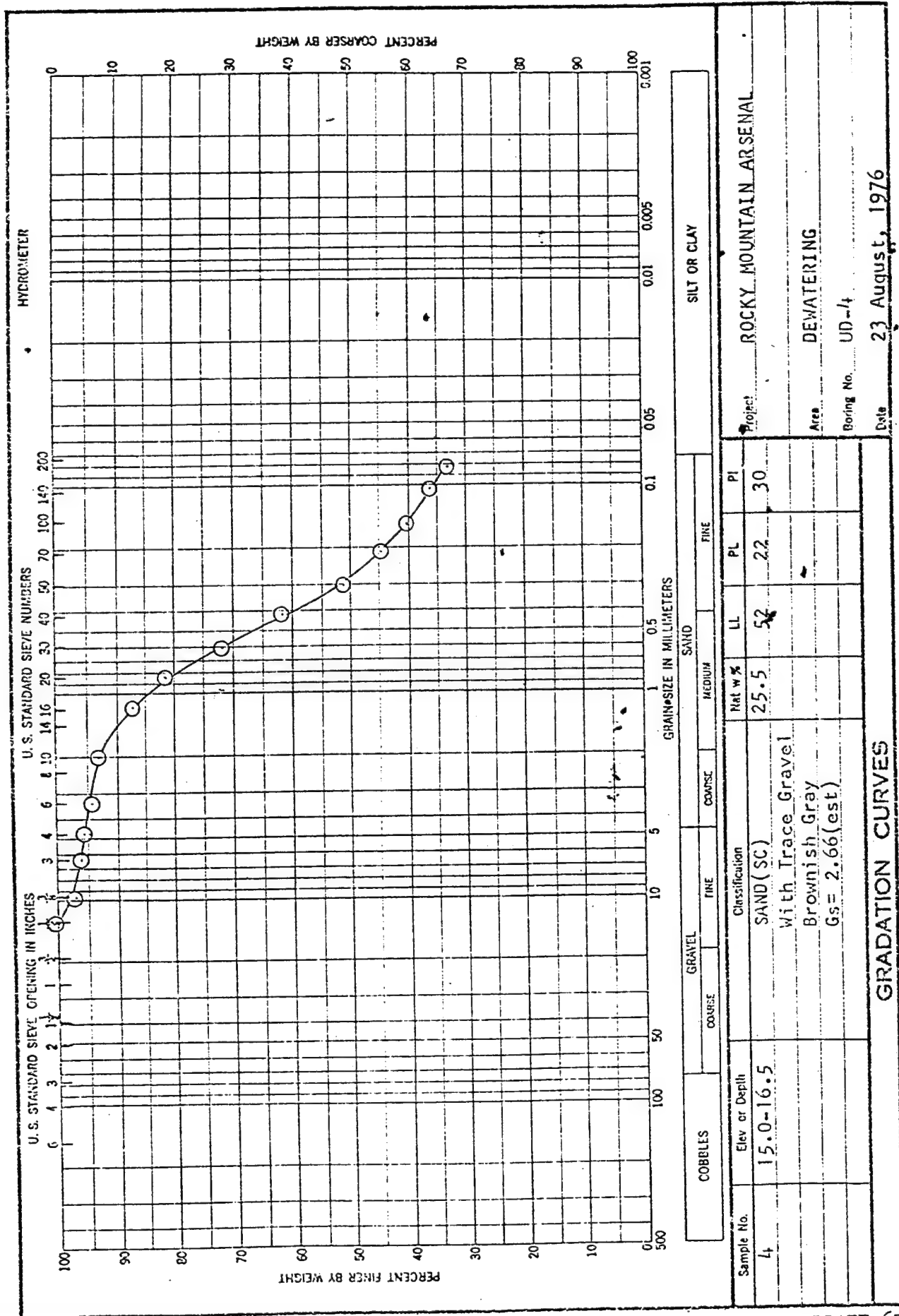
HYDROMETER

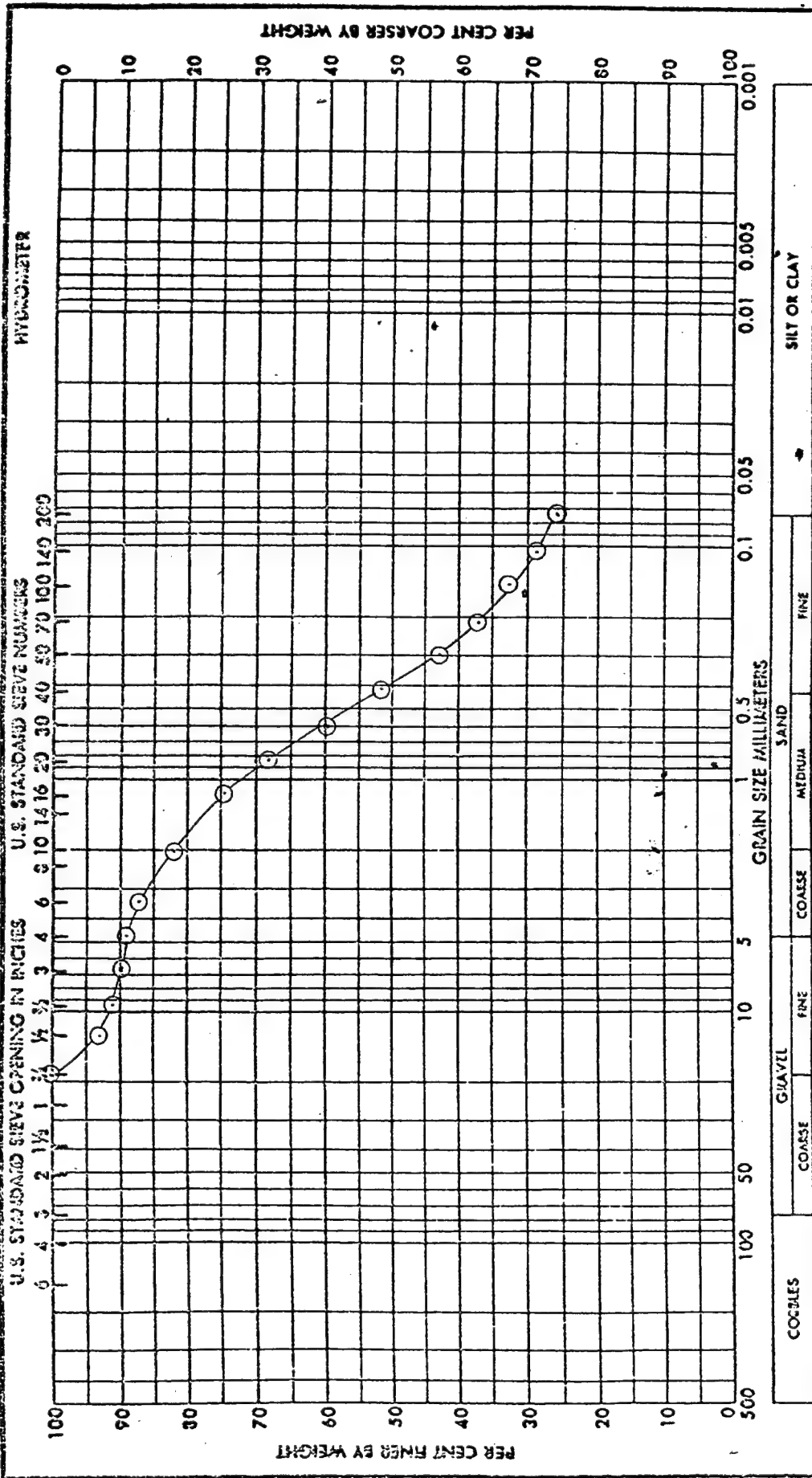
U.S. STANDARD SIEVE NUMBERS

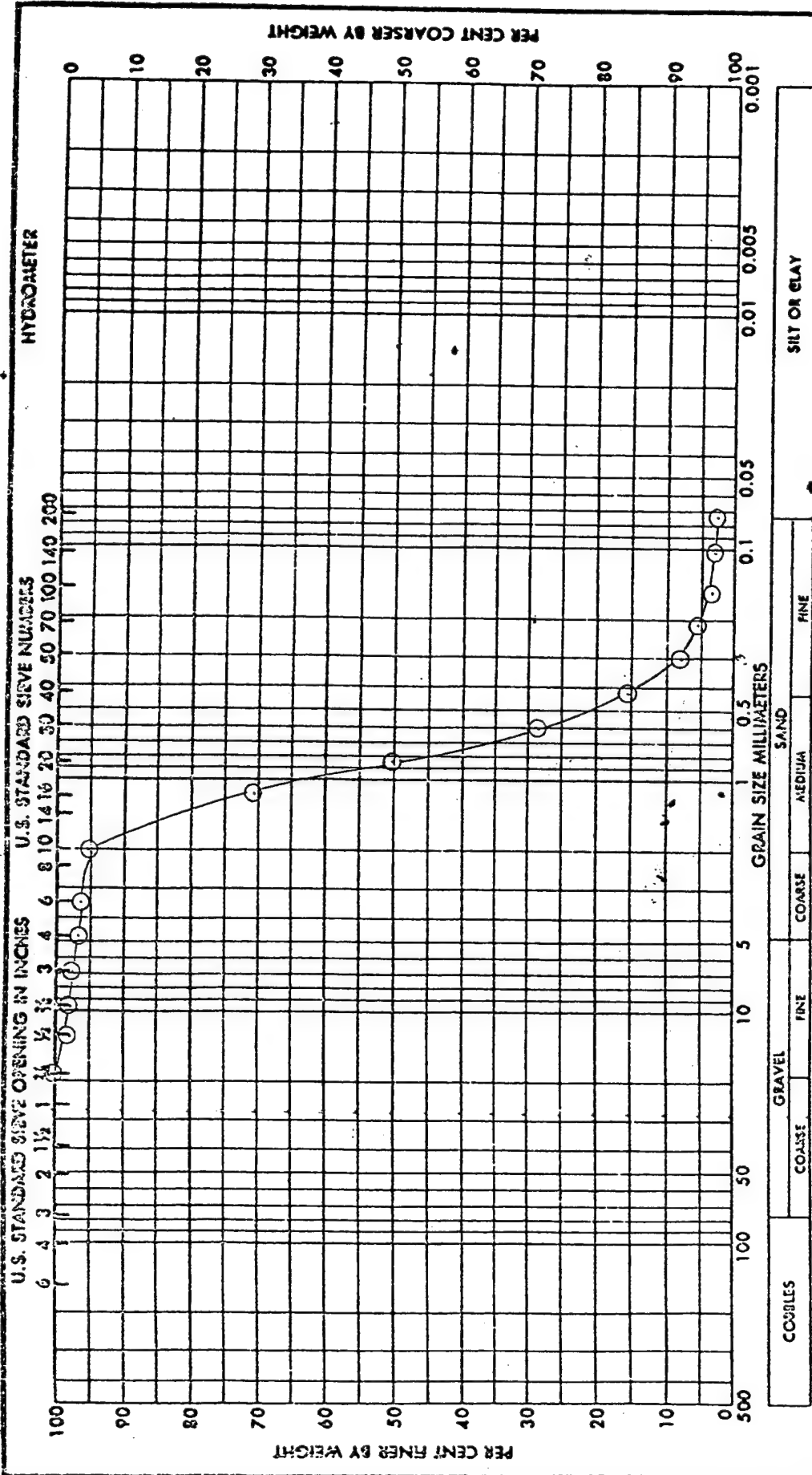
U.S. STANDARD SIEVE OPENING IN INCHES



COBBLES		GRAVEL		FINE SAND		SILT OR CLAY	
ELEV OR DEPTH		CLASSIFICATION		NAT W%		PROJECT	
5		SILTY SAND(SH)		24.3		ROCKY MOUNTAIN ARSENAL	
		BROWN					
		Gs = 2.66(est)				AREA	
						DEVATERING	
						BORING NO.	
						UD-3	
						DATE	
						3 Sept., 1976	

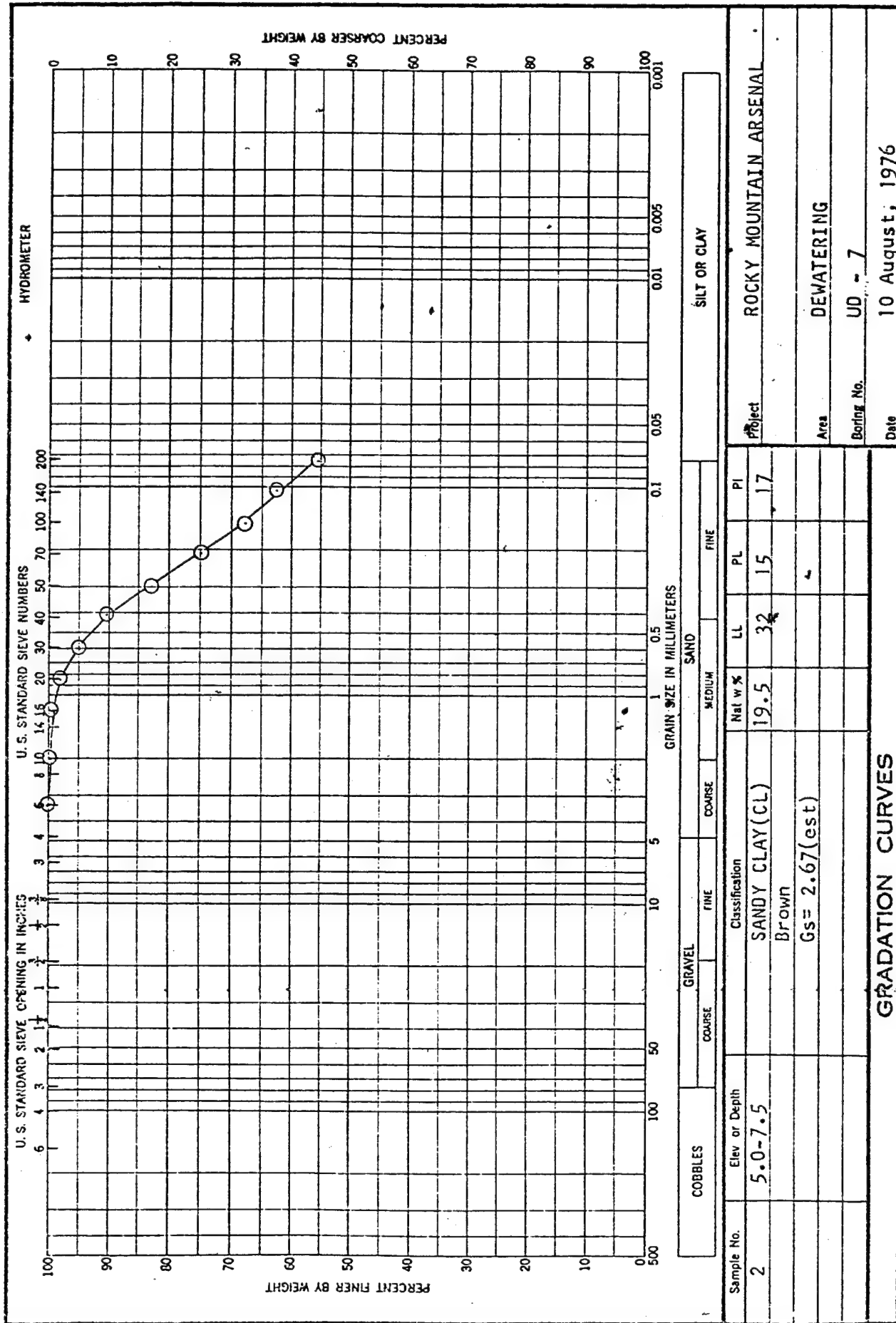




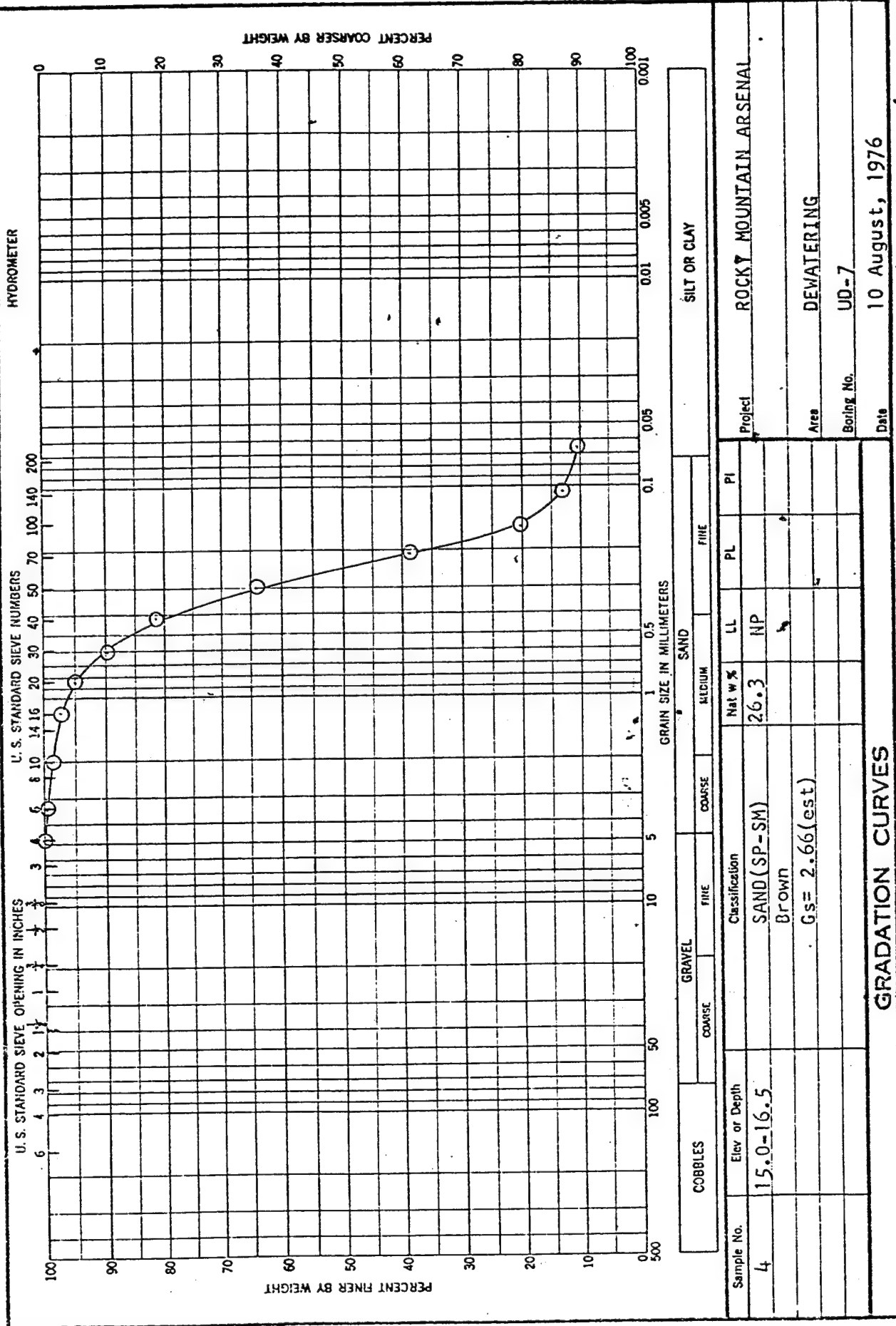


HYDROMETER		U.S. STANDARD SIEVE NUMBERS	
SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%
4	15.0-16.5	SAND (SP) BROWN	NP
		Gs = 2.65 (est)	
GRADATION CURVES			
PROJECT		ROCKY MOUNTAIN ARSENAL	
AREA		DEWATERING	
SCALING NO.		UD-6	
DATE		30 August, 1976	

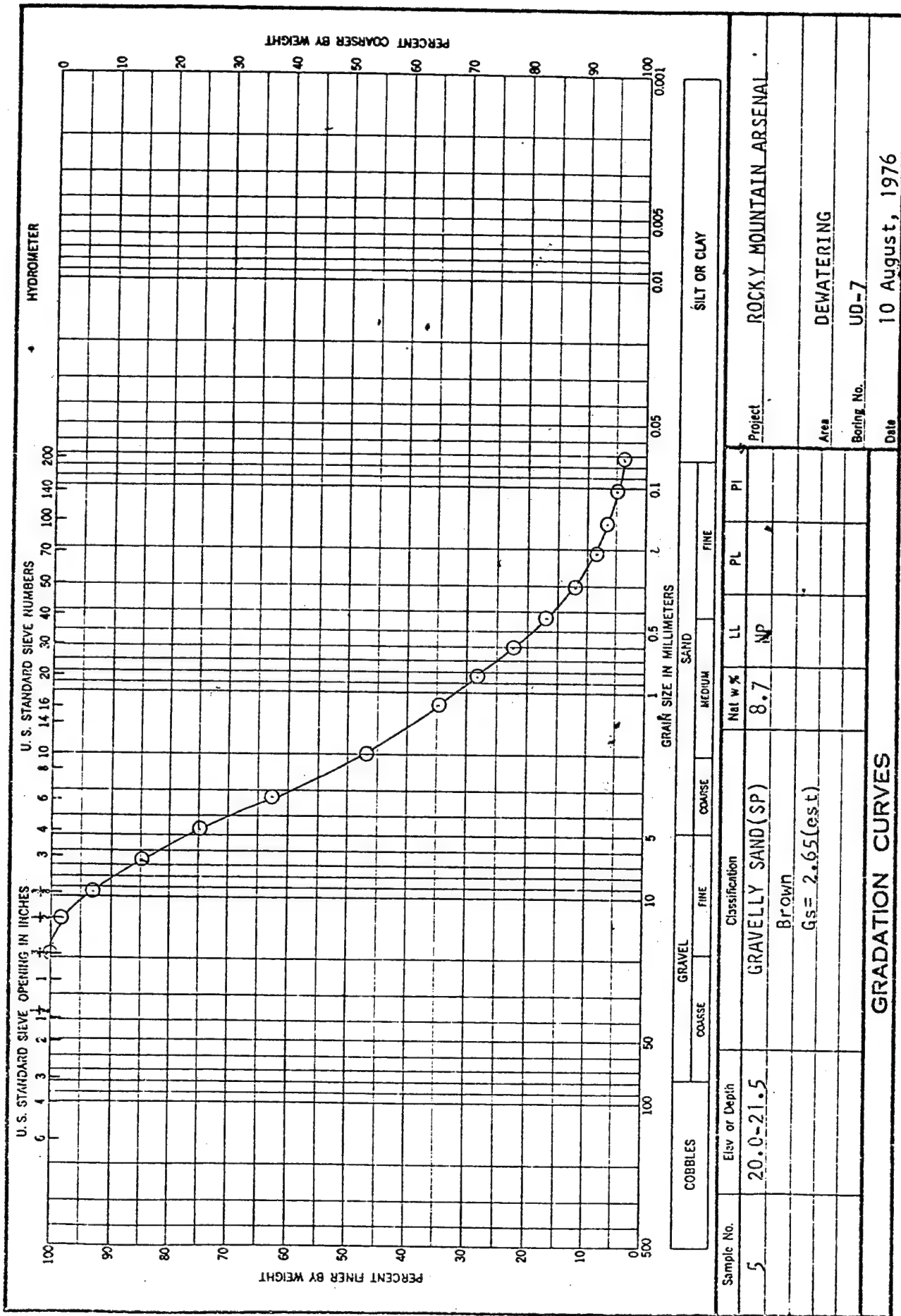
U.S. GOVERNMENT PRINTING OFFICE : 1953 OF - 70-118
 REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE.
 1 MAY 63
 2067
 Ag. $D_{10} = 0.32$
 $-200 = 3\%$



ENG FORM 2087
1 MAY 63



Ag. 0.10 less than 0.074 m.
-200 = 11%



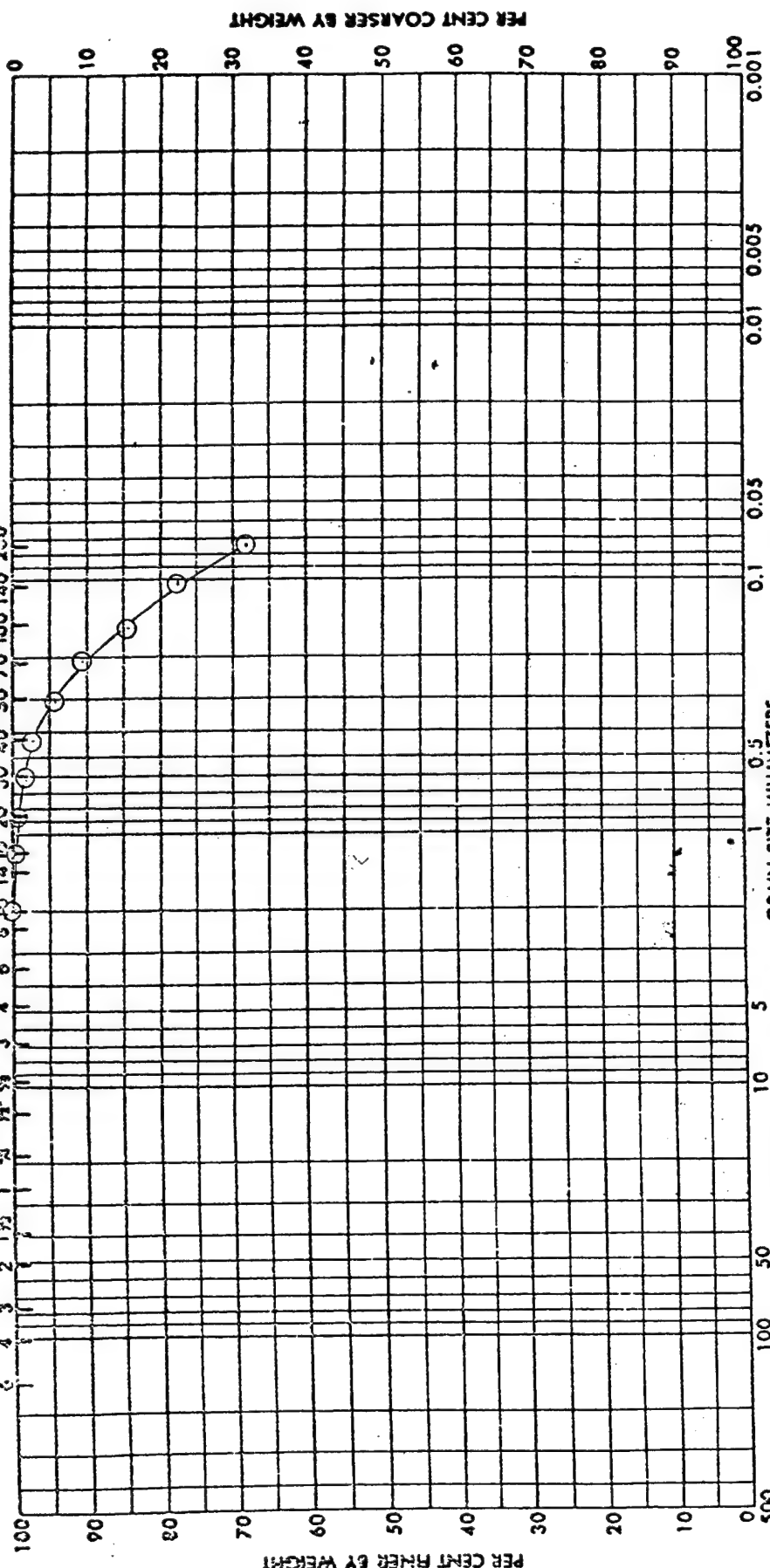
ENG FORM 1 MAY 63 2087

Ag. $D_{10} = 0.23$
 $-200' = 4\%$

HYDROPLASTER

U.S. STANDARD SIEVE OPENING IN INCHES U.S. STANDARD SIEVE NUMBERS

6 4 3 2 1 1/2 1 3/4 2 3/4 3 4 6 10 14 20 30 40 50 70 100 140 200



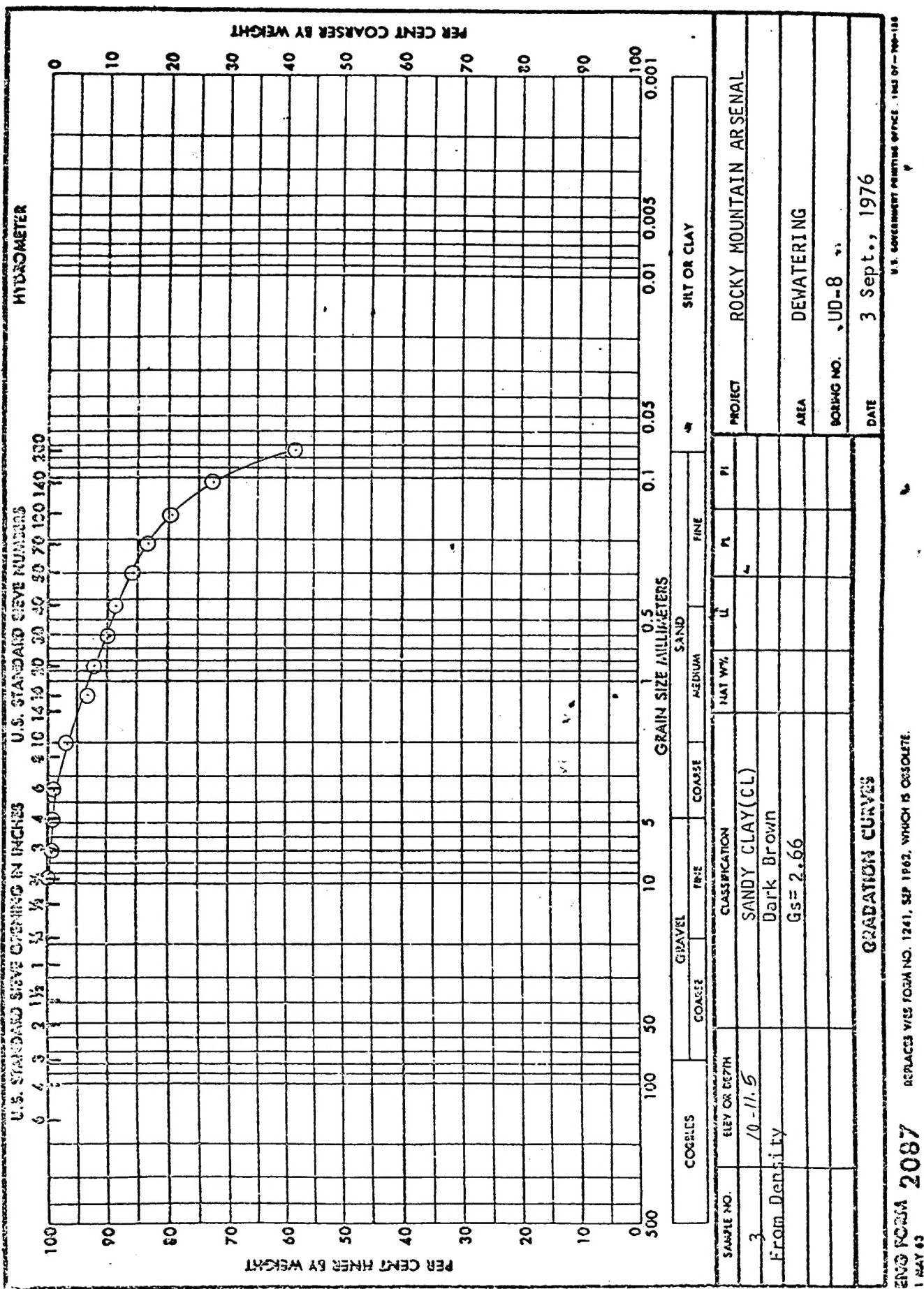
COBBLES		GRAVEL		FINE SAND		SILT OR CLAY	
COARSE		FINE		MEDIUM		FINE	
SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION		NAT W%	U _h	M	P
1	0-1.5	SANDY CLAY (CL)			42	19	23
From 0		Brown					
		G _s = 2.74					
GRADATION CURVES							
PROJECT				ROCKY MOUNTAIN ARSENAL			
AREA				DEWATERING			
BOILING NO.				UD-8			
DATE				3 Sept., 1976			

HYDROMETER

U.S. STANDARD SIEVE OPENING IN INCHES

U.S. STANDARD SIEVE NUMBERS

6 4 3 2 1 1/2 3/4 3/8 1/4 1/8 1/16 1/32 1/64 1/128 1/256 1/512 1/1024 1/2048 1/4096 1/8192 1/16384 1/32768 1/65536 1/131072 1/262144 1/524288 1/1048576 1/2097152 1/4194304 1/8388608 1/16777216 1/33554432 1/67108864 1/134217728 1/268435456 1/536870912 1/1073741824 1/2147483648 1/4294967296 1/8589934592 1/17179869184 1/34359738368 1/68719476736 1/137438953472 1/274877906944 1/549755813888 1/1099511627776 1/2199023255552 1/4398046511104 1/8796093022208 1/17592186044416 1/35184372088832 1/70368744177664 1/140737488355328 1/281474976710656 1/562949953421312 1/1125899906842624 1/2251799813685248 1/4503599627370496 1/9007199254740992 1/18014398509481984 1/36028797018963968 1/72057594037927936 1/144115188075855872 1/288230376151711744 1/576460752303423488 1/1152921504606846976 1/2305843009213693952 1/4611686018427387904 1/9223372036854775808 1/18446744073709551616 1/36893488147419103232 1/73786976294838206464 1/147573952589676412928 1/295147905179352825856 1/590295810358705651712 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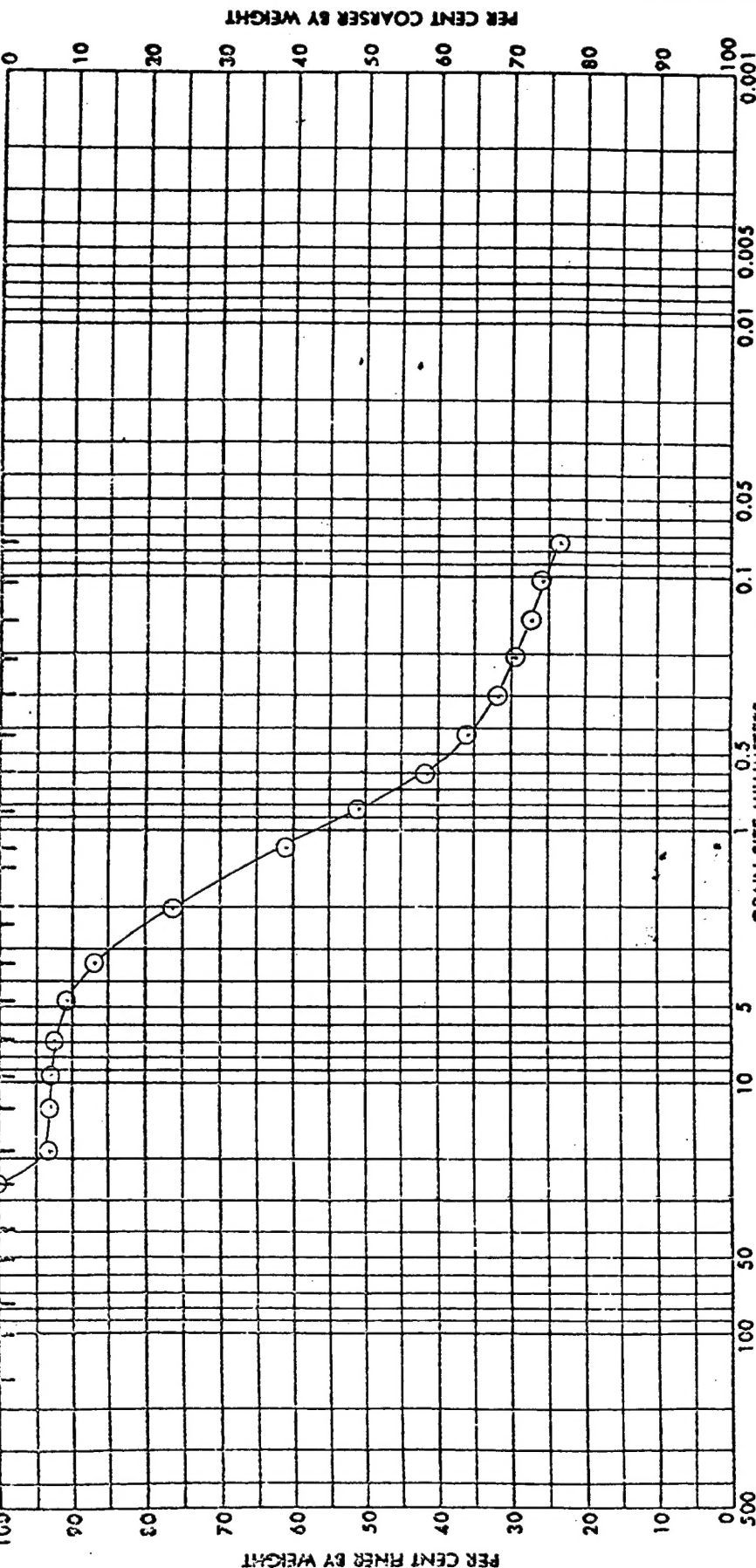


HYDROMETER

U.S. STANDARD SIEVE OPENING IN INCHES U.S. STANDARD SIEVE NUMBERS

U.S. STANDARD SIEVE OPENING IN INCHES U.S. STANDARD SIEVE NUMBERS

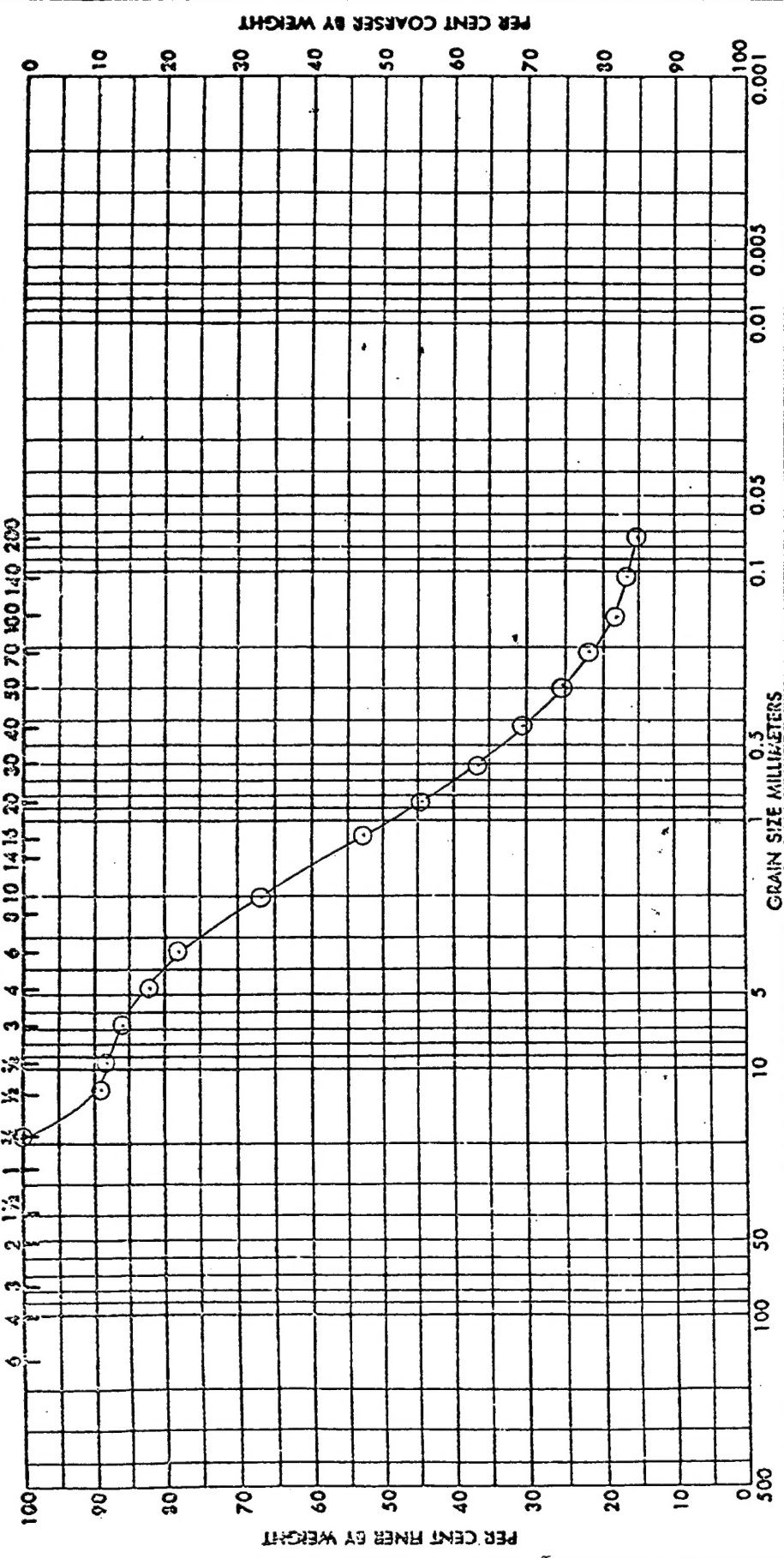
6 4 3 2 1 1/2 1 3/4 2 3/8 3 3/8 4 6 8 10 14 20 30 40 50 70 100 140 200



COBBLES		GRAVEL		SAND		SILT OR CLAY	
COARSE		FINE		COARSE		FINE	
SAMPLE NO.	ELEV OR DPTH	CLASSIFICATION	PLAT WT%	U _L	M	P _L	PROJECT
4	15.0-16.5	CLAYEY SAND (SC) With Gravel G _s = 2.66 (est)	20.2	35	15	20	ROCKY MOUNTAIN ARSENAL
Sample too small for representative gradation							AREA
							DEWATERING
							BORING NO.
							UD-8
							DATE
							3 Sept., 1976
GRADATION CURVES							

HYDROMETER

U.S. STANDARD SIEVE OPENING IN INCHES U.S. STANDARD SIEVE NUMBERS



COBBLES		GRAVEL		SAND		SILT OR CLAY	
COARSE		FINE		COARSE		FINE	
SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION		NAT W%	IL	PL	PI
5	20.0-21.5	CLAYEY, GRAVELLY SAND(SC)		32.3	62	22	40
		Tan					
		Gs = 2.68(est)					
Sample too small for representative gradation							
GRADATION CURVES							
PROJECT				ROCKY MOUNTAIN ARSENAL			
AREA				DEWATERING			
SCHEM NO.				UD-8			
DATE				3 Sept., 1976			

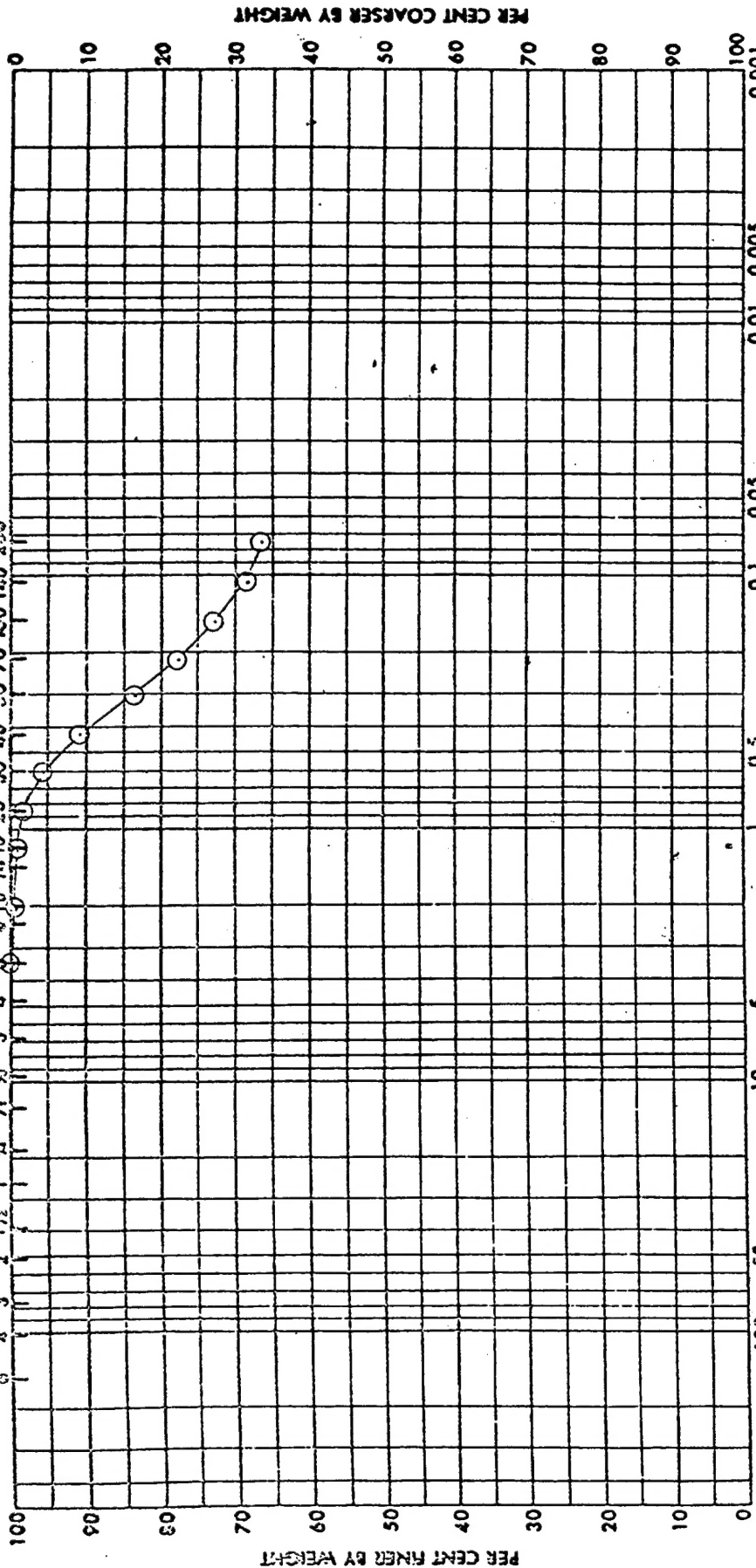
ENCL FOR 2087
 REPLACES WBS FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE.
 1 MAY 63
 U.S. GOVERNMENT PRINTING OFFICE: 1962 OF - 140-118
At 0.1% less than 0.075mm
 -200 = 152

HYDRO-MASTER

U.S. STANDARD SIEVE OPENING IN INCHES

U.S. STANDARD SIEVE NUMBERS

6 4 3 2 1 1/2 1 3/4 2 1/2 3 4 5 6 8 10 12 14 16 20 25 30 40 50 60 70 100 140 200



COBBLES		GRAVEL		SAND		SILT OR CLAY	
ELEV OR DEPTH		CLASSIFICATION		NAT W%		PROJECT	
25.0-26.5		SANDY CLAY (CH)		25.4		ROCKY MOUNTAIN ARSENAL	
		Dark Gray					
		Gs = 2.70 (est)				AREA DEWATERING	
						BORING NO. UD-8	
						DATE 3 Sept., 1976	

ENGINEERING FORM 2087 REPLACES WES FORM NO. 1241, SEP 1962, WHICH IS OBSOLETE. U.S. GOVERNMENT PRINTING OFFICE: 1963 OF-700-128